WASTE HEAT UTILIZATION FOR WOLLASTON LAKE, SASK.

WASTE HEAT UTILIZATION*

for Wollaston Lake, Saskatchewan

Prepared for

Saskatchewan Power Corporation

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UTILISATION DE CHALEUR RÉSIDUELLE À WOLLASTON LAKE (SASKATCHEWAN)

Résumé

L'étude porte sur la viabilité économique de la récupération de chaleur résiduelle de deux nouvelles génératrices diesel de 600 kVA qui seront installées dans une nouvelle centrale électrique à Wollaston Lake.

On examine la chaleur résiduelle comme source de chaleur pour un nouveau centre médical (en construction), une nouvelle école (proposée), une laverie automatique, le réseau d'alimentation en eau de l'est de la collectivité, et un certain nombre de maisons d'habitation.

Les résultats obtenus par l'étude des facteurs techniques peuvent s'appliquer à d'autres collectivités, sous réserve des compensations nécessaires pour tenir compte des différences de climat, des conditions du sol, des coûts du combustible, des frais de construction et de l'implantation spatiale de la collectivité.

Les auteurs devaient également se pencher sur les aspects sociaux et environnementaux de la question. Or, au cours de leurs entretiens avec des membres de la collectivité, ils ont constaté que le projet de chauffage urbain ne suscitait pas de préoccupation immédiate d'ordre social ou environnemental. C'est pourquoi aucune partie du rapport n'est consacrée à ces questions.

L'étude permet de constater qu'il y a suffisamment de chaleur résiduelle produite par les moteurs diesel des génératrices pour fournir à tous les utilisateurs nommés l'énergie nécessaire pour leurs besoins moyens en chaleur pour l'hiver, et une partie de leurs besoins de pointe. La portion des besoins de pointe qui serait satisfaite dépendra de la coincidence de la demande.

La récupération de la chaleur résiduelle des gaz de carneau et gaz d'échappement est relativement coûteuse. Puisque la chaleur résiduelle de la chemise d'eau suffit pour satisfaire à la plupart des besoins en chaleur, il ne convient de retenir la récupération de la chaleur des gaz de carneau qu'à titre d'énergie d'appoint, lorsque la rentabilité est assurée.

La viabilité d'un réseau de chauffage à distance est grevée par les coûts élevés des installations souterraines. Ainsi, les systèmes les plus rentables seront ceux où les grands utilisateurs se trouvent à proximité de la centrale.

À titre de première approximation, la distance maximale entre la nouvelle école de Wollaston Lake et la centrale ne devrait pas dépasser quelque 600 à 800 mètres, selon la longueur de la saison de chauffage, afin que l'option soit rentable. Ces chiffres sont fondés sur une période d'amortissement de 15 ans. La rentabilité n'augmente qu'à peine pour une période d'amortissement de 30 ans.

Il y a 1 000 mètres de distance (d'après la longueur de la tuyauterie) entre l'école dont la construction est projetée et la centrale de Wollaston. Si le coût du mazout augmente au rythme de l'inflation, le projet deviendra marginal avec le temps.

Le coût du mazout représente une variable très importante. S'il augmente à un taux inférieur à celui de l'inflation, le projet de Wollaston n'est pas économique. En revanche, un taux de croissance supérieur au taux d'inflation pourrait lui assurer une certaine rentabilité.

La rentabilité du projet dépend aussi de la demande et de l'inflation. L'inflation fait généralement en sorte que le projet se rentabilise avec le temps. Plus le taux d'inflation est élevé, plus le projet devient économique. Si, de surcroît, on choisit des consommateurs dont la demande augmente avec le temps, les deux facteurs combinés plaident nettement en faveur du projet.

Du point de vue des utilisateurs résidentiels, le coût du service ne compensera pas immédiatement le coût des canalisations et des échangeurs de chaleur. Avec un taux d'inflation moyen de 7,8 %, il faut plus de 10 ans pour compenser le coût d'un service résidentiel à Wollaston.

À moins que l'école et la centrale ne soient assez rapprochées l'une de l'autre, il n'est pas recommandé d'implanter un système de chauffage urbain à Wollaston avant que la rentabilité de ce mode de chauffage n'ait été démontrée ailleurs.

De tous les sites que nous avons examinés, nous croyons que Deschambault serait le plus indiqué pour l'installation d'un système de chauffage urbain, pour les raisons suivantes: la centrale est située en face de l'école, juste de l'autre côté de la rue; l'usine de traitement des eaux municipales se trouve à moins de 200 mètres de la centrale, d'autres établissements, tels que les résidences des professeurs et l'arène municipale, sont situés dans un rayon de 250 mètres de la centrale; Deschambault est facile d'accès par la route, ce qui est avantageux sur le plan des coûts de construction; le mazout ne coûte pas beaucoup moins cher qu'à Wollaston. Cependant, on songerait, semble-t-il, à déménager la centrale dans un avenir rapproché. Aussi, avant de choisir un autre site, il y aurait lieu de discuter avec la collectivité en cause des conséquences d'un déménagement si la centrale était déplacée loin de son emplacement actuel.

À la lumière d'un examen assez superficiel, nous avons classé les différents sites considérés par ordre de potentiel décroissant: Deschambault, Stony Rapids, Wollaston Lake, Southend.

Dans le cas de Stony Rapids, de Wollaston Lake et de Southend, la rentabilité sera, au mieux, longue à venir et dépendra de facteurs économiques très fluctuants, comme l'inflation, le coût du mazout, la croissance de la demande de chaleur et la longueur de la saison de chauffage.

Au moyen d'un système de chauffage urbain, on aurait de bonnes chances d'économiser 100 000 litres ou plus de mazout chaque année à Wollaston et dans plusieurs autres collectivités.

Le chauffage urbain, tel qu'il est défini dans cette étude, peut être économique pour le service de distribution public et pour le consommateur. Il peut faire réaliser des économies de mazout considérables, à condition toutefois que la source de chaleur soit assez proche du point de consommation.

L'étude a été réalisée par l'Associated Engineering (Sask.) Ltd. pour la Saskatchewan Power Corporation, à l'aide d'une contribution financière des Affaires indiennes et du Nord Canada et du Programme de démonstration dans les collectivités éloignées d'Énergie, Mines et Ressources Canada.

1.0 EXECUTIVE SUMMARY

The Saskatchewan Power Corporation (SPC) commissioned Associated Engineering (Sask.) Ltd. [AESL] to undertake a study to investigate the economic viability of recovering heat from two new 600 kVA diesel generator sets to be installed in a new power station located at Wollaston.

The waste heat was considered as a source of heat for the new health clinic which is presently under construction, the proposed new school, a laundromat, the east side community water system, and some residences.

The technical results of this investigation may be applied to other communities subject to transformations to account for differences in climate, soil conditions, fuel costs, construction costs and the community layout.

Social and environmental issues were to be a part of this report. However, in discussions with the community, it became apparent that the proposed district heating system did not raise any immediate social and environmental concerns. Consequently, there is no special section in this report on these issues.

The investigation indicates that there is adequate heat available from the generator diesel engines to serve all the users identified with their mean winter heat requirements and a portion of their peak heating needs. The portion of peak heating needs served will depend on coincidence of demand.

Flue gas or exhaust gas heat recovery is relatively expensive. Since most of the heating requirements can be met with water jacket heat, flue gas heat should be considered only as an add-on where it is economically justifiable.

The viability of a district heating system is impacted greatly by the high cost of the underground piping systems. Consequently, the most viable systems will be those where the major user is located close the generating facility.

The initial economic distance for serving the new school at Wollaston is approximately 600 to 800 metres depending on the length of the heating season. This is based on a 15 year capital recovery. The economics only improve marginally for a 30 year life.

The proposed school and generating station at Wollaston are 1000 metres apart based on pipe run. If fuel oil costs are escalated at inflation, the project becomes marginal with time.

Fuel oil costs are a highly sensitive variable. If fuel costs increase at a a rate less than inflation, the project at Wollaston is not economical. If fuel costs increase at a rate greater than inflation then it can become economical.

The economics are also sensitive to demand and inflation. Inflation tends to make any of the systems more economical with time. The higher the inflation rate, the more economical the project becomes. In addition, if customers are selected whose demand will increase with time, these two factors are cumulative in favour of the project.

Service costs for residential users do not immediately cover the cost of their service pipe and heat exchanger equipment. With an average inflation rate of 7.8%, it will take over 10 years to offset the cost of a residential service in Wollaston.

Unless the school and generating station can be located relatively close to each other, a district heating system at Wollaston should not be undertaken until viability is proven elsewhere.

In examining the other sites, it is recommended that Deschambault be considered for a district heating system before any others in this study because: the generating station is located immediately across the street from the school; the proposed community water treatment plant is located within 200 metres of the generating station; other facilities such as

teacherages and the community arena are located within 250 metres of the generating station; Deschambault is readily accessable by road, consequently, construction costs should be favourable; and fuel costs are not significantly less than at Wollaston. However, it is understood that there are plans to relocate the generating station in the near future. The implications of relocating the plant any significant distance from its current location should be discussed with the community before a new site is selected.

The priority for development of district heating systems from highest potential to least potential, based on relatively cursory examinations, is as follows:

a) Deschambault;
b) Stony Rapids;
c) Wollaston Lake; and
d) Southend.

Return on investment for Stony Rapids, Wollaston Lake and Southend will be long term at best and subject to economic vagaries such as inflation, fuel costs, heat demand growth and length of the heating season.

There is a good potential for saving 100 000 litres or more of fuel oil each year using district heating in Wollaston or several other communities.

District heating as outlined in this study can be economical for the utility, the consumer, and can result in considerable fuel oil savings, provided the consumers are located reasonably close to the source of the generated heat.

2.0 INTRODUCTION

2.1 PURPOSE OF STUDY

The purpose of the study was primarily to determine if it is economical to use waste heat from the diesel generators at Wollaston Lake to supply heat to the new school.

Other potential customers and the economics of serving them were also to be examined.

The Terms of Reference and letters modifying the Terms of Reference are contained in Appendix K.

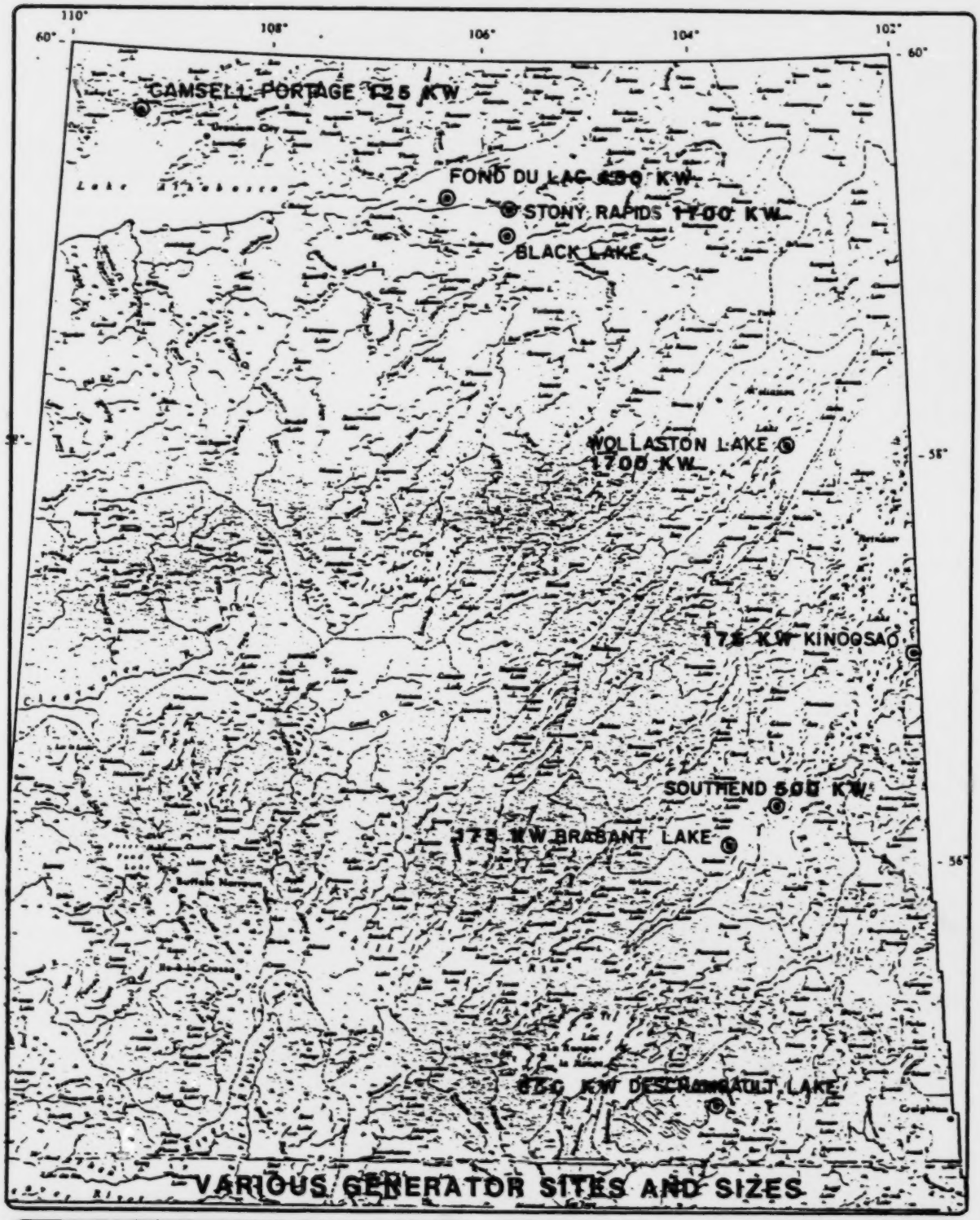
The key items identified were evaluation of the technical aspects of heat recovery from diesel generators, both water jacket and flue gas heat; heat metering; piped delivery systems; customer equipment; maximum, minimum and average heat supply; sensitivity analysis of the economics of heat supply; applicability to residential heat supply; and extrapolation of the results of the Wollaston study to other northern communities.

The other communities to be examined included Stony Rapids, Southend and Deschambault. The location of all the communities and the proposed or installed generating capacities is shown on Figure 1.

2.2 LOCATION

This isolated community is located on the east side of Wollaston Lake on the shores of Welcome Bay. Geographically, it is located 58° 5' 30'' north latitude and 103° 10' 0'' west longitude.

It is 193 kilometres southeast of Stony Rapids and 92 kilometres west, by air, from Brochet, Manitoba.



CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
AESL	DATE / DWG No **FIG. 1**
BCIL 5590A-AES	JOB No.

The community is not directly accessible by road. In the summer, materials and supplies are barged across the lake. In winter, an ice road is constructed across the lake. For extended periods in the fall and spring, the only access is by air.

2.3 POPULATION

There are approximately 440 Chipewyan reserve Indians, of which approximately 40% live in the off-reserve area. There are also approximately 170 white and non-status Indians in the off-reserve area, bringing the total population to approximately 610.

2.4 CLIMATE

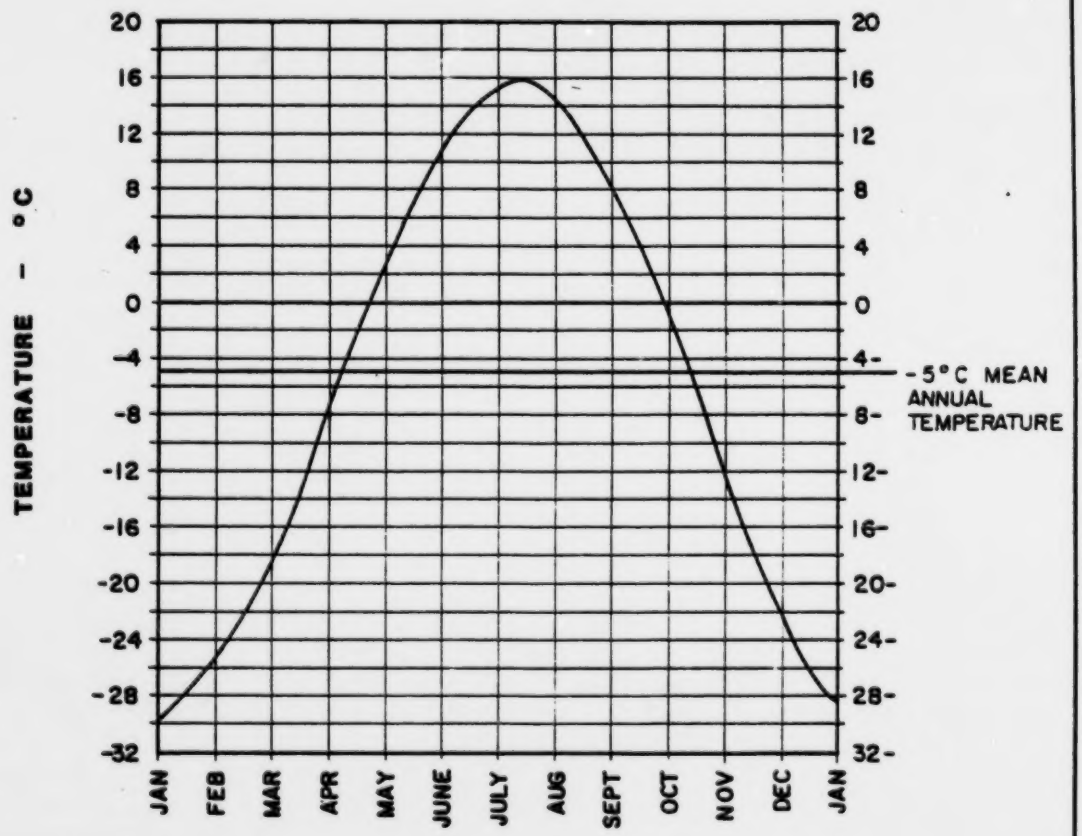
Climatic data is not available for Wollaston. The nearest climatic data available is for Brochet, Manitoba, as follows:

Table I - Climatic Data

Average Annual Precipitation	416 mm
Average Annual Snowfall	1390 mm
January Mean Daily Maximum Temperature	-24°C
Januarv Mean Daily Minimum Temperature	-33.9°C
July Mean Daily Maximum Temperature	20.1°C
July Mean Daily Minimum Temperature	10.5°C

Mean daily air temperatures are shown on Figure 2, based on information at Brochet.

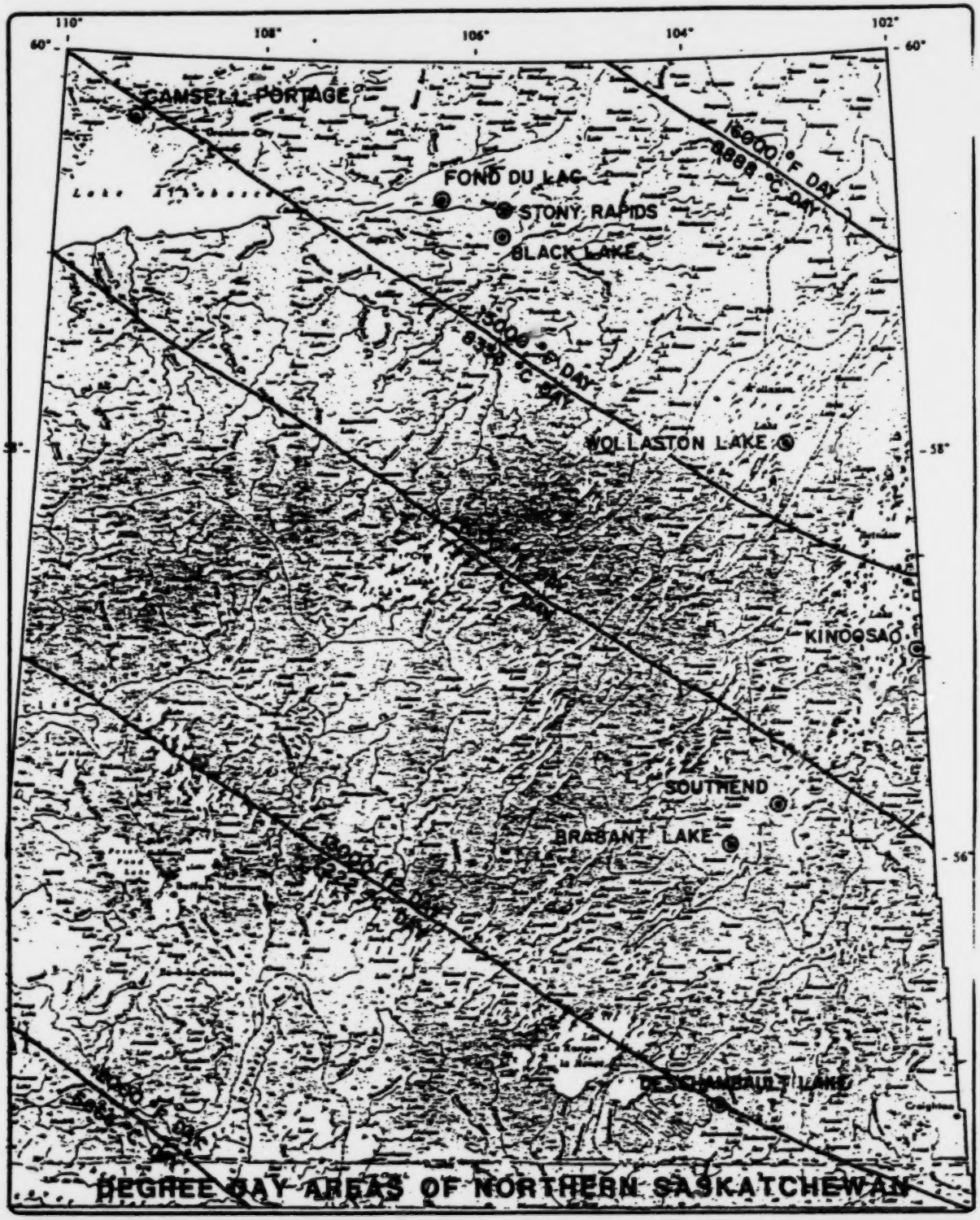
In order to translate data for Wollaston to other areas, the degree day curve information on Figure 3 can be used. This figure allows general climatic comparisons to be made from area to area.



MEAN DAILY AIR TEMPERATURES

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / DATE / JOB No.
	SCALE: FIG. 2

BCIL 5590A-AES



CLIENT/PROJECT	SUBJECT
SPC CO·GENERATION STUDY	
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / DATE / JOB No. / SCALE / DWG No. FIG. 3

BC1L 3390A-AES

2.5 POWER SUPPLY

Two 250 kVA and one 300 kVA diesel generators currently provide the power supply at Wollaston Lake.

Two new 600 kVA generators are to be transferred from Pinehouse. The 300 kVA generator is to be removed.

Electrical power rates charged in 1984 by North Sask Electric are as follows:

Residential: Basic charge $ 4.65 per month; 3.98¢/kW·h for first 315 kW·h; 19¢/kW·h for balance

General Commercial: Basic charge $ 6.05 per month, including first 30 kW·h; 7.9¢/kW·h for next 420 kW·h; 26¢/kW·h for balance

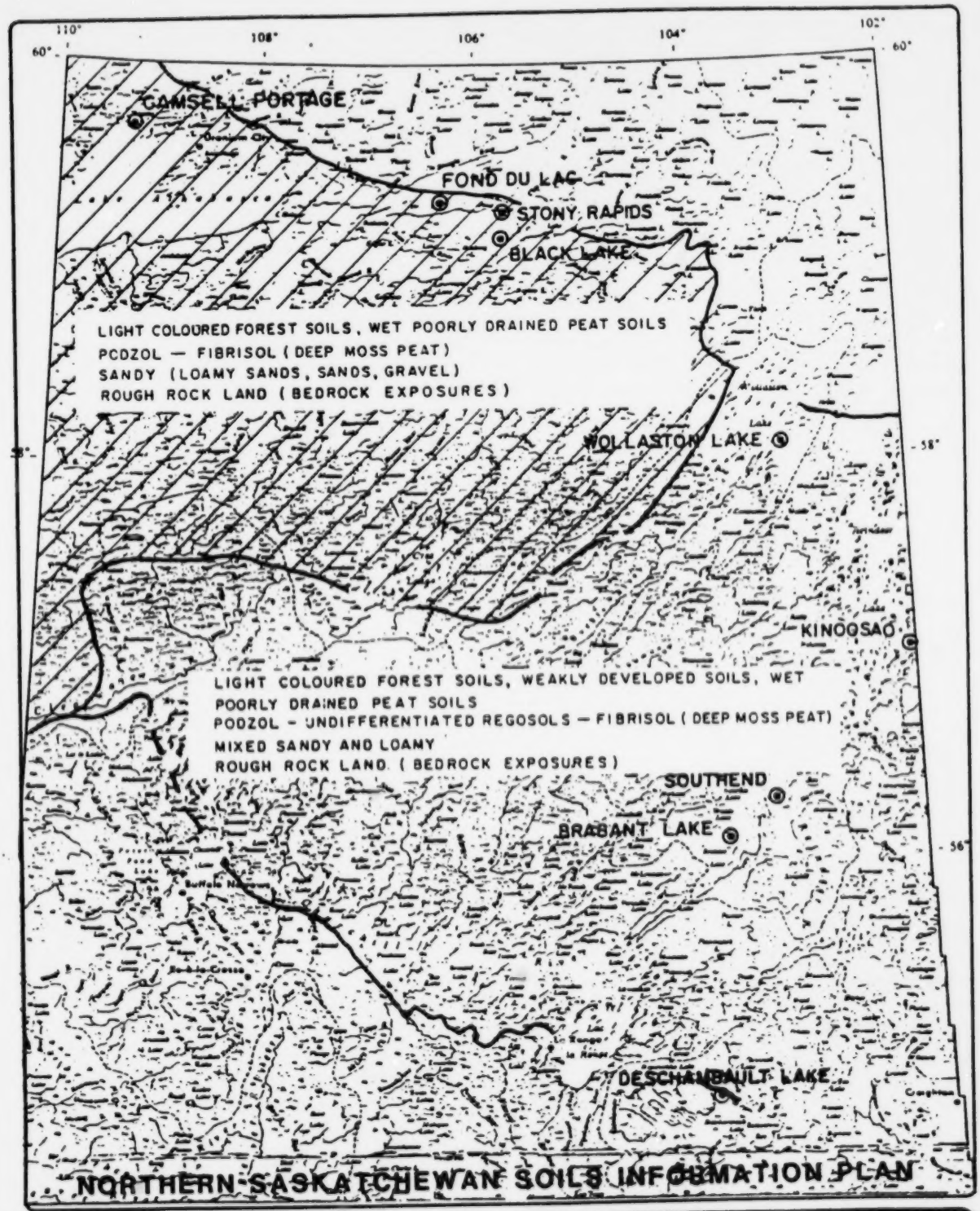
Government Commercial: 38¢/kW·h

2.6 FUEL SUPPLY

The Saskatchewan refined petroleum product retail price forecast from Canadian Energy Trends 1983 estimated a price in 1984 for commercial diesel fuel as $ 0.306 per litre. This was found to be the quoted price for 1984 fuel at Wollaston. It will fluctuate depending on tenders for fuel delivery to Wollaston Lake. Fuel is barged into Wollaston and stored for long periods due to the isolation of Wollaston.

2.7 TOPOGRAPHY AND SOILS

The area consists of rolling hills covered with a coniferous forest. The top surface usually consists of organic decay and mosses over sand layers with variable moisture and gravel content. Certain layers have



CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
AESL	DATE / DWG No **FIG. 4**
	JOB No

BCIL 3390A · AES

boulders scattered throughout. Precambrian granite bedrock is generally encountered 2 to 3 metres below the surface. Sporadic pockets of permafrost may be encountered from year to year as Wollaston is in an area of "intermittent" permafrost. The average lake level is 396 metres above mean sea level.

Generalized soils information for northern Saskatchewan is shown on Figure 4.

No soil logs were available for the east side of the lake. Soils information for the west side, prepared by Keith Gabriel Partnership for the Municipal Services Branch, Department of Northern Saskatchewan, were examined.

The following is the assumed soil stratigraphy used as the basis for the computer analysis:

Table 2 - Soil Stratigraphy

Depth [cm]	Moisture Content [%]	Dry Density [kg/m^3]
0 - 30	3	2000
30 - 150	9	2000
150 - 270	7	2000
270 - 300	16	2000
300 - 510	0	2500

Thermal conductivity values for frozen and unfrozen soils were taken from Kerstein's charts [Ref. 7] using soils parameters described earlier. Heat capacities were calculated for the various soil layers using the same parameters.

The "Temps" computer program was used to calculate the temperatures in the soil system using one-dimensional finite difference techniques (Appendix H).

From the calculated daily soil temperatures, the variations in annual temperatures at selected depths were compiled. The envelope of maximum and minimum soils temperatures were also compiled for use in determining pipe heat losses at various depths.

3.0 AVAILABLE WASTE HEAT

3.1 EXISTING EQUIPMENT

A new generating station is to be built on the east side of Welcome Bay. The project has recently been tendered and construction is pending.

Two new Caterpillar D398, 600 kVA diesel electric generators to be transferred from Pinehouse by North Sask Electric (NSE) for installation in the new building. Two existing 250 kVA machines in the community are to be retained for emergency use only.

The new machines have air cooled radiators to reject heat from the engine water jacket through which ethylene glycol is circulated. Each machine has a shell and tube heat exchanger sized to provide sufficient heat to supply the estimated structural, infiltration, combustion air, and ventilation air heat losses for the generator building. Heat energy not required by the heat exchanger is rejected at the radiator. Only one heat exchanger needs to run to provide heat for the building. The other exchanger would not be required even if two generators were operating.

On the secondary side of the heat exchangers, glycol solution is circulated to unit heaters, baseboard heaters and a fresh air heating coil mounted on a wall. This coil heats the combustion air and any makeup air required to replace air exhausted by an associated roof exhaust fan.

Associated with each generator, there is a roof exhaust fan and a fresh air makeup air system. Each fresh air system consists of a weather cowl, damper, mixing box with re-circulation damper, filter, and vane axial supply fan.

3.2 THERMAL BALANCE

From thermal data supplied by the generator manufacturer and typical heat balance curves for a turbo-charged engine as published by ASHRAE, systems volume for 1976, the curves on Figure 5 were drawn based on the following table. Generator electrical output is approximately 30% of the fuel energy content.

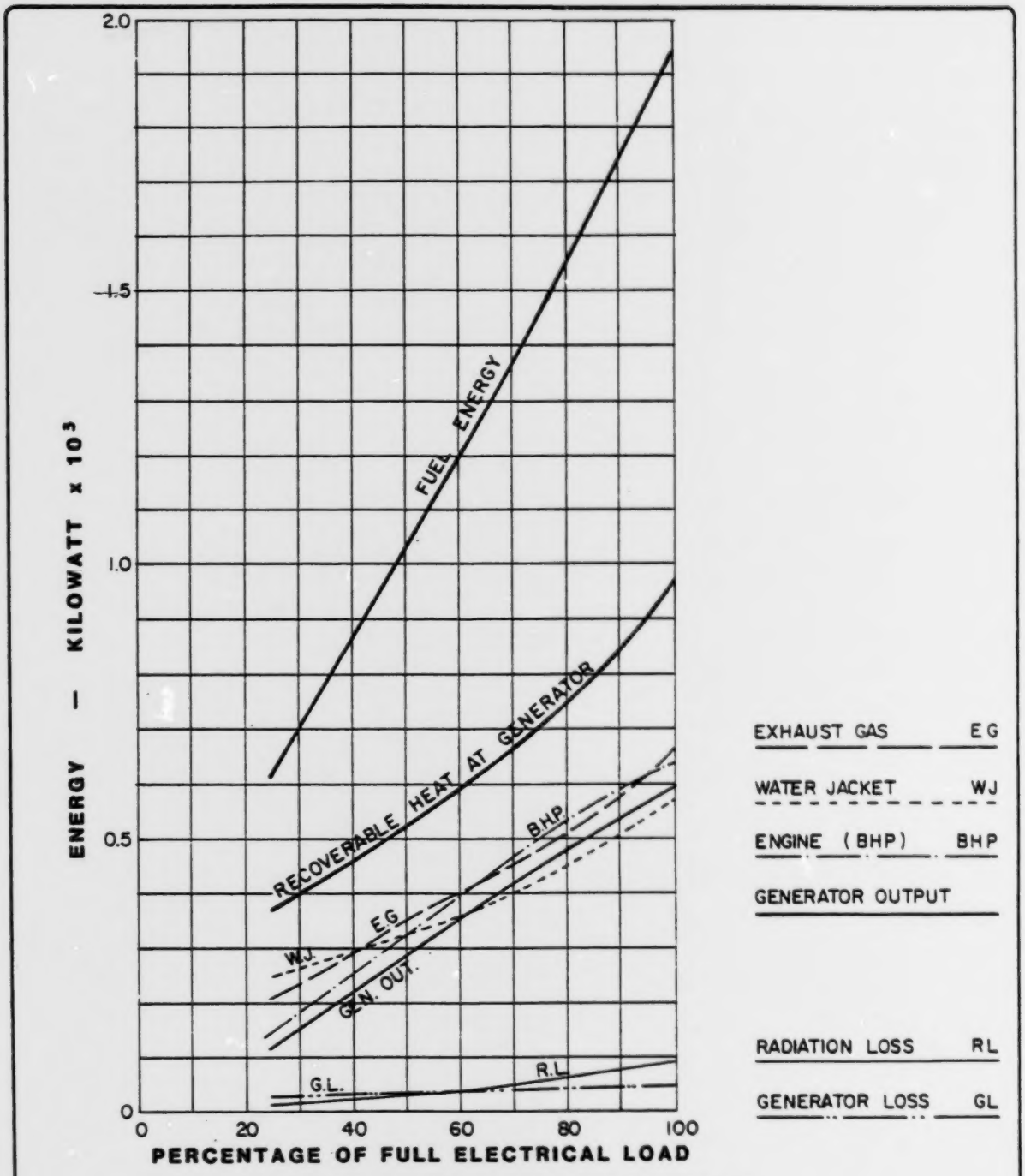
Table 3 - Recoverable Heat

Electrical Load [%]	Generator [kW]	Recoverable Water Jacket [kW]	Recoverable Exhaust [kW]	Total Recoverable Heat [kW]
100	600	570	400	970
90	535	510	348	858
80	480	450	309	759
70	420	400	270	670
60	350	360	240	600
50	290	320	210	530
40	220	290	174	464
30	150	260	141	401
25	120	250	123	373

Water jacket and exhaust heat are in the range of 30% to 33% of fuel energy content when the generator is operating from 40% to 100% full electrical load. The after cooler and oil cooler loads are included in the graph for the engine jacket water.

Not all heat is recoverable from the exhaust system. The manufacturer specified a limit of 163°C on the exhaust gas leaving temperature to prevent problems with condensation and corrosion from acids formed with the products of combustion.

The engine supplier does not recommend operation of the engine below 25% load unless control is provided to maintain the jacket water temperature at not less than 85°C. With temperature control, the low limit of operation has been set at 15% electrical load which approximates estimated night time demand. Flow through the engine should be such as to limit the temperature rise in the jacket to 8°C.



ESTIMATED HEAT BALANCE FOR 600 KVA DIESEL GENERATOR

CLIENT/PROJECT **SPC CO·GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / SCALE
	DATE / DWG No **FIG. 5**
	JOB No.

BCIL 3590A · AES

3.3 ANALYSIS OF ELECTRICAL DEMAND

The monthly electrical consumption records over the period 1979 to 1983 were analysed as were the peak monthly demands from 1973 to 1983. These were obtained from North Sask Electric (NSE) in La Ronge.

Figure 6 is an estimated daily load curve prepared by SPC for a typical weekday and weekend at Wollaston Lake.

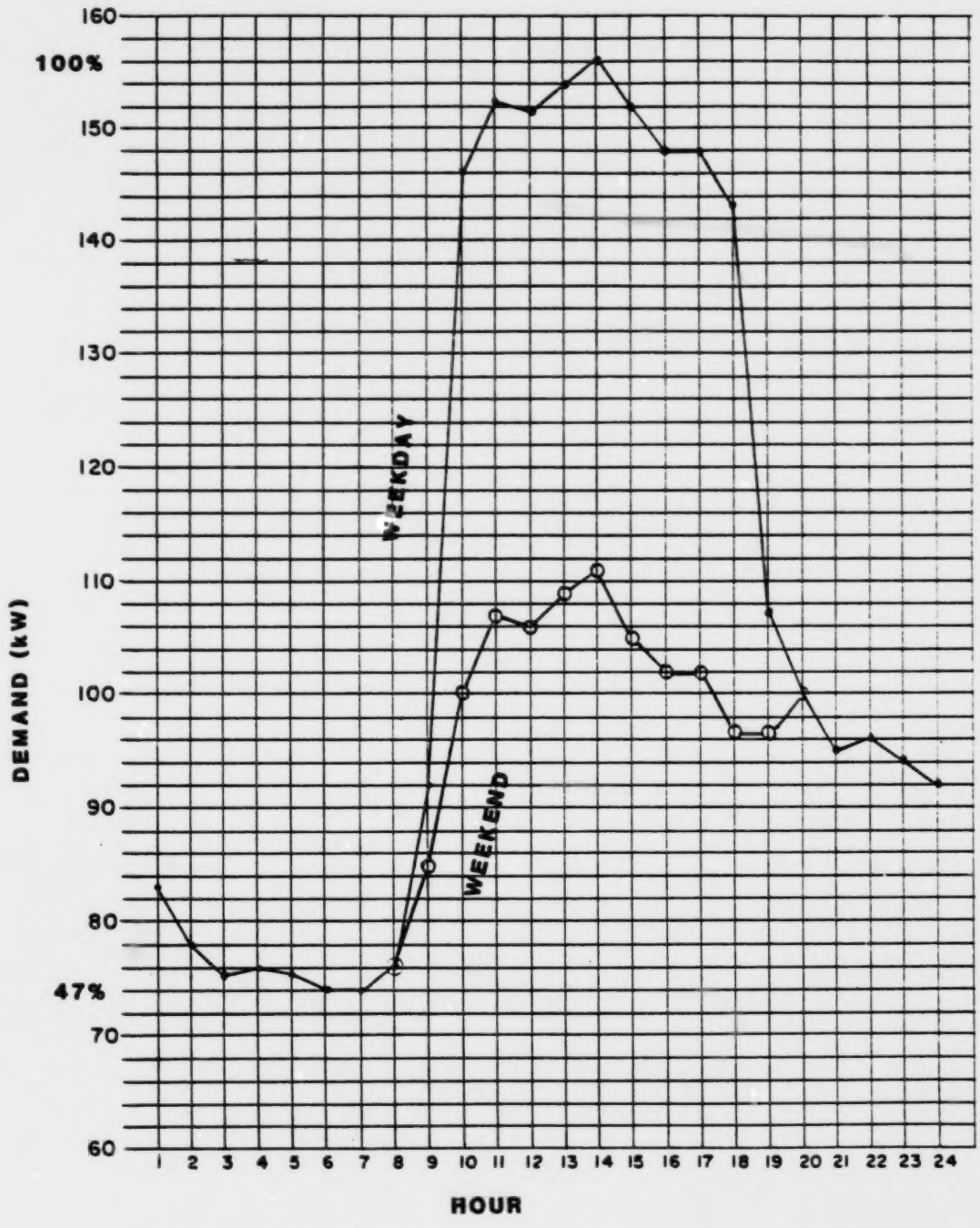
Analysis of the data from NSE highlighted trends in the peak month and mean month peak demands with time. The mean and minimum demands trend upwards with time as shown on Figure 7. The peak month and mean month peaks approximate a power growth curve. NSE estimates a peak of 400 kW when the school is built which corresponds favourably with mid 1985 on Figure 7. The growth in peak month consumption and mean month consumption follows a more linear relationship with time as can be seen from Figure 8.

The slope of this curve will change if consumption increases through the use of more electrical appliances such as 240 volt stoves which are presently not allowed by North Sask Electric.

The bands for projected mean and minimum demands shown on Figure 7 were obtained by trending the mean demands based on recorded consumption and the ratio of recorded peaks to mean demands. It is expected that as the peaks grow parabolically the means may be deflected from a linear growth.

As no recorded minimum demands are available, it has been assumed that the growth will be proportionally similar to that of the mean trend.

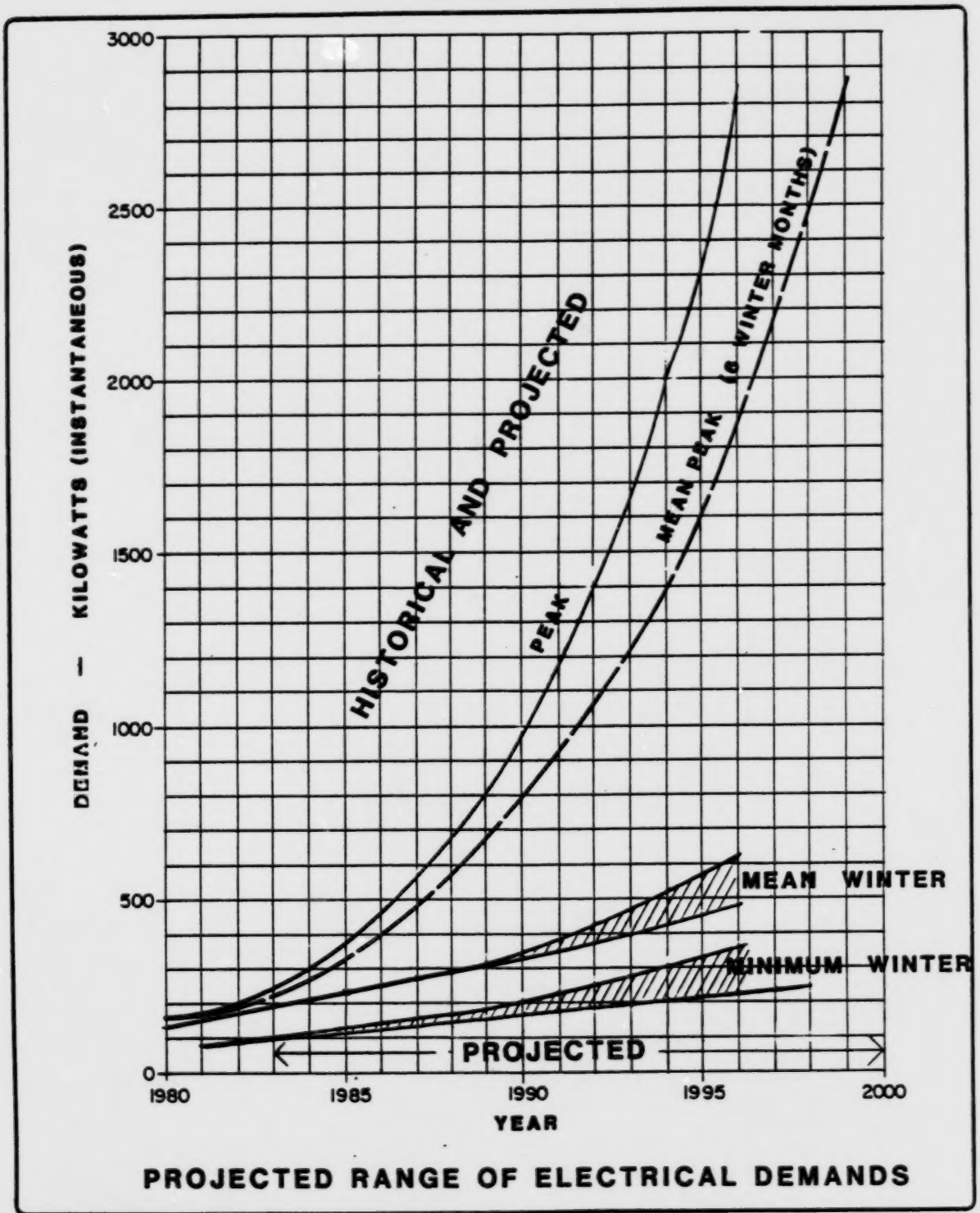
The curves illustrated on Figure 8 were used to determine the peak month and mean month generator demands in order that the available waste heat could be estimated.



TYPICAL DAILY CONSUMPTION CURVE 1981

CLIENT/PROJECT **SPC CO·GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / DATE / JOB No — SCALE — DWG No **FIG. 6**

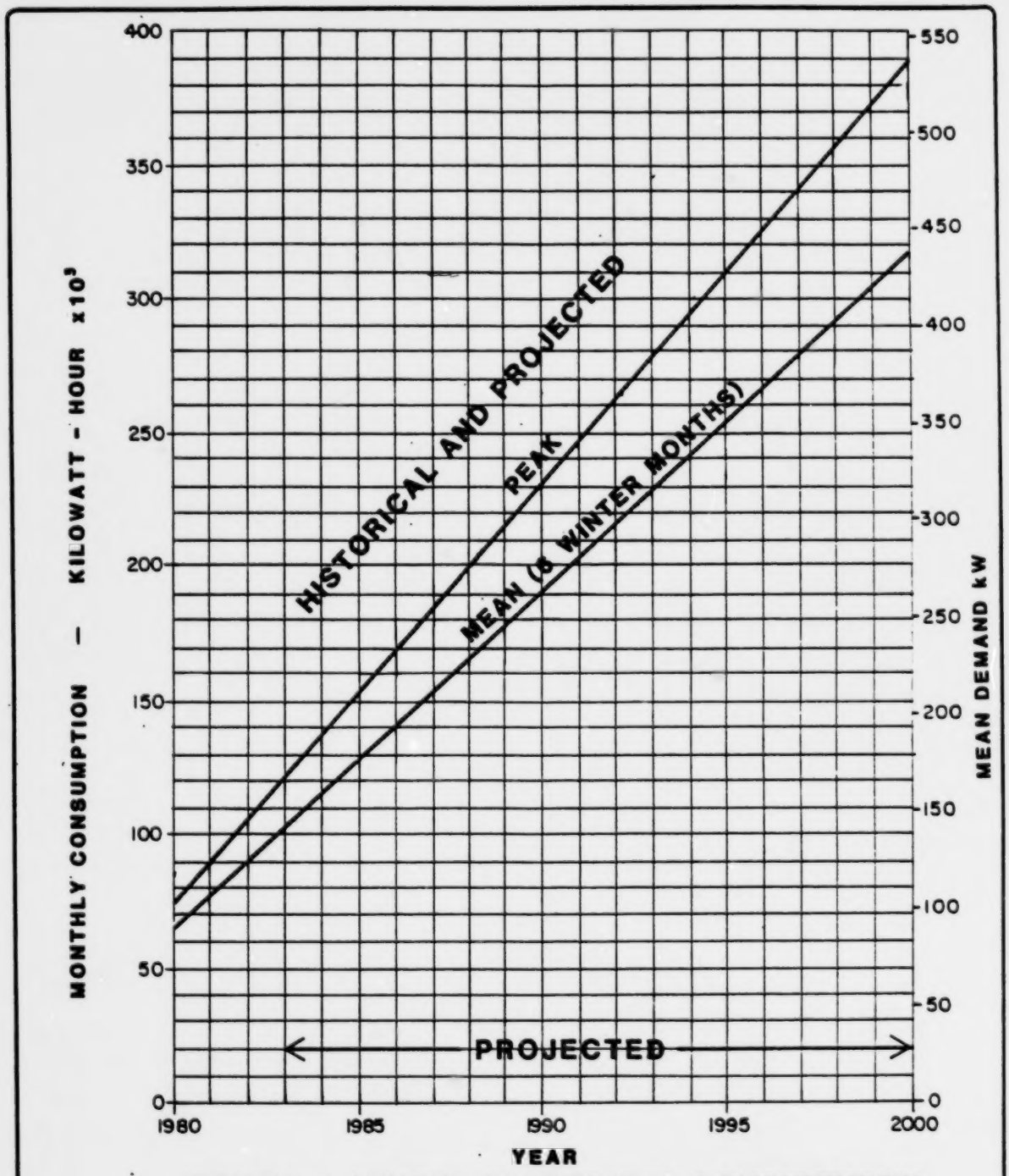
BCIL 5590A · AES



PROJECTED RANGE OF ELECTRICAL DEMANDS

CLIENT/PROJECT **SPC CO·GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE DATE / DWG No **FIG. 7** JOB No.

BCIL 3590A · AES



MONTHLY WINTER ELECTRICAL CONSUMPTION
HISTORICAL AND PROJECTED

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
	DATE / DWG No **FIG. 8**
	JOB No

BCIL 3390A - AES

This curve was used to develop available waste heat projections to determine what size heat market could be served.

Since recoverable heat is directly related to electrical demand for any given period of the day, it was necessary to establish typical daily and monthly consumption figures which would be representative of Wollaston and other northern communities.

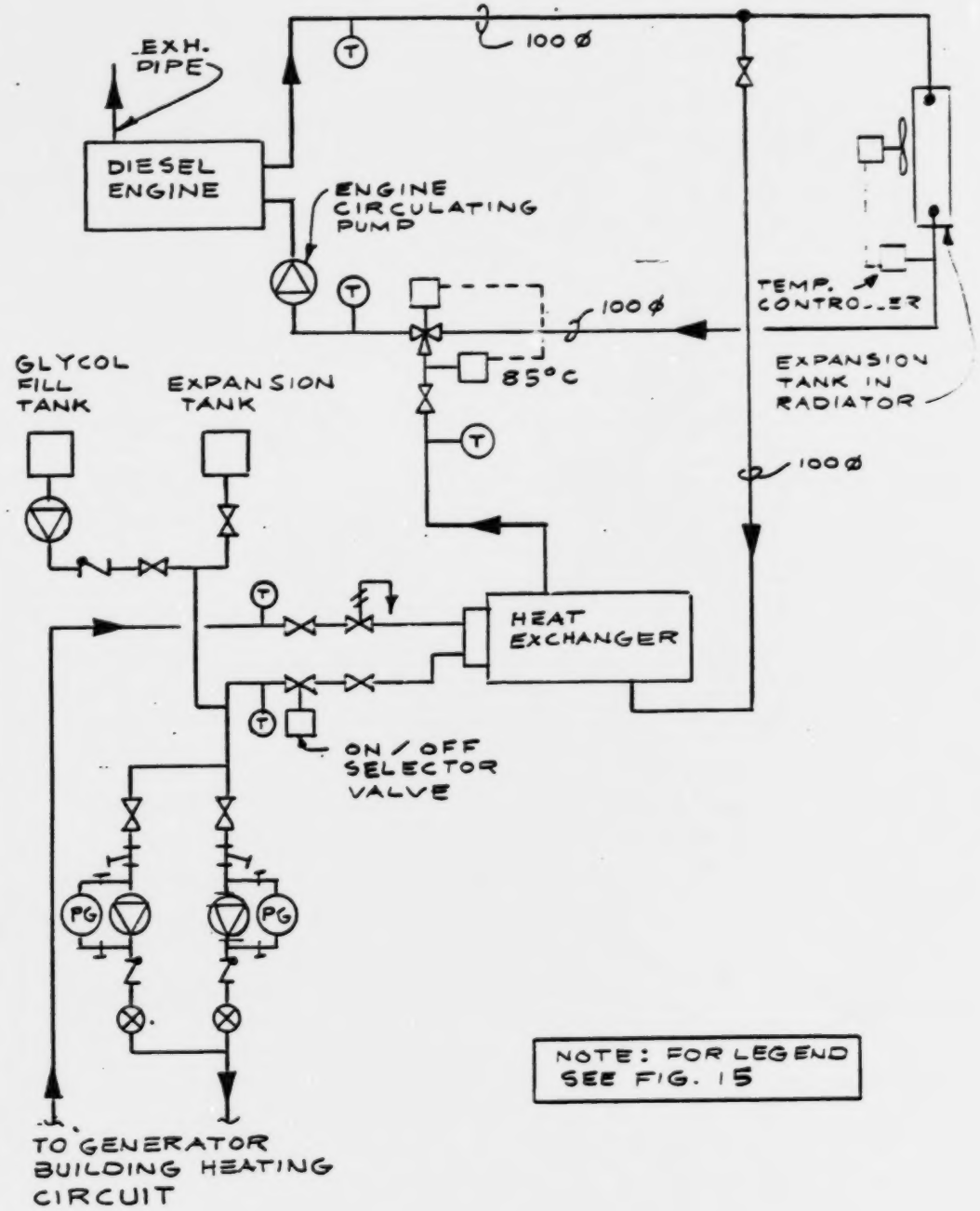
The estimated daily load curve (Fig. 6) clearly shows a rapid increase in demand during weekdays between the hours of 8:00 to 10:00 in the morning when people get up and businesses open for the day. The demand remains fairly steady throughout the day dropping to about 50% of the peak load between the hours of 9:00 in the evening to 7:00 in the morning the following day.

The shape of this curve in winter is expected to remain the same. Growth in the peak, mean and minimum values will cause it to elongate as demand increases in the future.

3.4 HEAT RECOVERY EQUIPMENT

Figure 9a shows the schematic of the proposed generator building heat recovery system. The proposed operation is described in this section under item 3.5.

Figure 9b shows the proposed changes to the primary engine cooling circuits to serve the existing heat exchangers 1 and 2 and the proposed heat exchanger 3 which would serve the potential heat market with waste heat from the engine jacket only. The piping and valves are such that either primary system can serve its generator heat exchanger and heat exchanger 3.



PRESENT PIPING SCHEMATIC TYPICAL BOTH ENGINES

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / DATE / JOB No. — SCALE — DWG No **FIG. 9A**

BCIL 3590A-AES

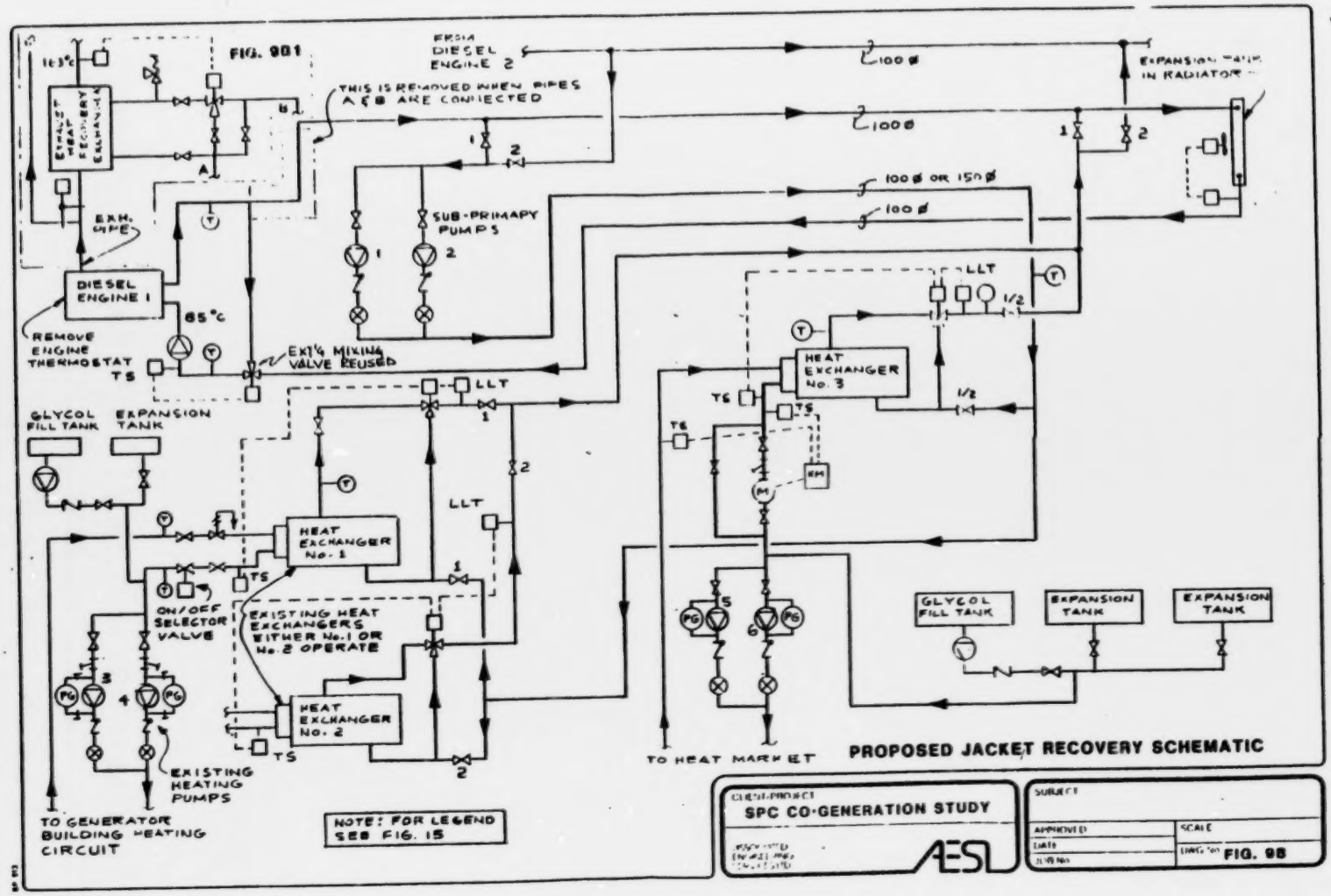


FIG. 98.1
FROM DIESEL ENGINE 2
THIS IS REMOVED WHEN PIPES A & B ARE CONNECTED
100 ø
100 ø
EXPANSION TANK IN RADIATOR
100 ø OR 150 ø
100 ø
SUB-PRIMARY PUMPS
EXH. PIPE
DIESEL ENGINE 1
REMOVE ENGINE THERMOSTAT
65 °C
EXT'G MIXING VALVE REUSED
LLT
HEAT EXCHANGER No. 3
GLYCOL FILL TANK
EXPANSION TANK
HEAT EXCHANGER No. 1
ON/OFF SELECTOR VALVE
EXISTING HEAT EXCHANGERS EITHER No. 1 OR No. 2 OPERATE
HEAT EXCHANGER No. 2
EXISTING HEATING PUMPS
TO GENERATOR BUILDING HEATING CIRCUIT
TO HEAT MARKET
GLYCOL FILL TANK
EXPANSION TANK
EXPANSION TANK
NOTE: FOR LEGEND SEE FIG. 15
PROPOSED JACKET RECOVERY SCHEMATIC
SPC CO-GENERATION STUDY
AESL
SUBJECT
APPROVED
DATE
SCALE
DWG No FIG. 98

Glycol is circulated by two parallel operating pumps from the flow pipe to the engine radiator, to heat exchanger 3 and its associated generator heat exchangers 1 or 2. The generator not operating would have its main circuit valves closed and its heat exchanger isolated.

The control systems for heat exchangers 1 and 2 would be modified to provide direct control of the secondary circuit temperature by modulating a three-port bypass mixing valve. The existing three-port valve would be reused as a safety bypass control on the primary to ensure the return liquid temperature to the engine did not drop below 85°C.

Each bypass mixing valve which controls the heat exchanger outputs would have a low limit thermostat in the return line to the primary loop to override the secondary flow temperature control to limit the return temperature to 85°C.

The secondary circuit to the district heating market would be equipped with a heat meter to record the heat being pumped from the station. Again, parallel operating pumps are selected to provide a level of flow reliability in the event of a pump failure.

One or two large expansion tanks would be required to accept the expansion of the liquid in the secondary system as it is heated to operating conditions depending on the size of the distribution pipeline.

Since the secondary heat distribution will be used to heat potable water, it is proposed that the heat transfer liquid be a 50/50 solution of non-toxic propylene glycol.

It is recommended that the toxic ethylene glycol solution in the engine cooling system be changed to propylene glycol in case there is cross contamination between primary and secondary systems and secondary system and potable water system.

It should be noted that the concentration of propylene glycol is difficult to determine by measuring specific gravity. Three hygrometers, graduated to 3 decimal places, may be needed to cover the range of specific gravities, with the readings being compared with a calibration curve prepared in a laboratory. The refractive index or Karl Fisher analysis of water are the preferred laboratory methods of determining its concentration.

If heat is to be extracted from the exhaust gases, the piping and vent pipe have to be changed to accommodate a gas to liquid heat exchanger shown on Figure 9b area 9b1. The output of the exchanger is controlled by a three-port bypass mixing valve which is controlled by a low limit gas sensor to limit the leaving gas temperature to 163°C. There is a risk of condensation occurring and the formation of corrosive acids if the temperature drops below 163°C.

3.5 OPERATING PHILOSOPHY OF GENERATING FACILITIES

1. Present Operation:

a) Ventilation Systems:

The heating and ventilating systems designed for the generator building can accommodate four 600 kVA diesel generators in service.

Each of the 4 air supply systems is interlocked with a generator.

Each of the exhaust fans is interlocked with a generator.

When a diesel generator is operating its associated supply system will operate continuously and its exhaust fan will operate if the room temperture demands it. The vent damper at the wall mounted coil will open to 50%.

The following is the sequence of fan operations and damper positions with generator operation:

Table 4 - Ventilation Fan Operation

Winter Mode

No. of Generators Running	No. of Exhaust Fans Running	Upper Vent Damper (% open)	Lower Vent Damper (% open)
0	0	0	0
1	0	50	0
1	1	50	0
2	0	100	0
2	1	50	0
2	1	50	0
3	0	100	100
3	1	100	0
3	2	100	0
3	3	Condition blocked	
4	0	100	100
4	1	100	0
4	2	100	0
4	3	Condition blocked	
4	4		

Summer Mode

No. of Generators Running	No. of Exhaust Fans Running	Upper Vent Damper (% open)	Lower Vent Damper (% open)
0	0	0	0
1	0	100	0
1	1	100	0
2	0	100	0
2	1	100	0
2	2	100	0
3	0	100	100
3	1	100	100
3	2	100	100
3	3	100	100
4	0	100	100
4	1	100	100
4	2	100	100
4	3	100	100
4	4	100	100

The supply fan runs continuously and the fresh air, re-circulation air dampers modulate to the demand of a supply system thermostat mounted near the engine.

It is noted that there is no low limit control on the supply system. Therefore, there is nothing to prevent the supply air temperature dropping below freezing when the engine load exceeds 66%. To maintain an acceptable minimum low limit temperature of +5°C, the room temperature would have to be controlled at 28°C. If this temperature is not acceptable, a low limit control would have to be installed.

The exhaust fans are each controlled by their own room thermostat. If the space temperature rises, at a pre-selected temperature, the exhaust fan of the operating engine will switch on. Since it is capable of removing more than twice the volume that can be delivered by the supply system, the extra air required will flow into the building through the heating coil on the wall. This imposes an instantaneous load on the heating coil and heat exchanger reducing the potential usable heat for other buildings.

The controls are arranged to permit only two fans to operate during the winter. During the summer all four exhaust fans may operate depending on the thermostatic demand.

b) Heat Exchangers:

The primary flow through each existing heat exchanger is controlled by a three-way mixing valve. The valve modulates to maintain a constant discharge temperature of 85°C on the primary circuit. This is the minimum acceptable return temperature to the engine. The intent is to divert glycol from the primary circuit to the radiator to the heat exchanger. The

secondary circuit temperatures run wild, depending on heating load on the building and the heat transfer characteristics of the exchanger. There will be a definite time lag in control valve operation and system response.

c) Unit Heaters:

Unit heaters are permanently connected to the secondary glycol circuit. The fans are thermostatically controlled with manual adjustment.

In view of the large amount of heat given off by an engine to the space, it is unlikely that the fans would operate very often.

d) Pumps:

The secondary pumps are manually operated. One pump is standby to the one operating. The plant operator has to switch on standby in the event of operating pump failure. This may be a problem if the station is left unmanned for any great length of time. A more reliable pump operation is to select the pumps to run in parallel. In the event of failure, one will continue to run at a decreased total flow but at an increased individual pump flow.

2. Recommended Operational Changes:

It is imperative that the exhaust fans be prevented from operating when the outside ambient is less than 5°C. This can be done by wiring a low limit thermostat into the control circuit of the exhaust fan set to open when the outside air temperature is less than 5°C. If this method is chosen, it would be necessary to control the room temperature at a minimum of 28°C, otherwise, the supply temperature would drop below +5°C.

An alternative method of controlling the space temperature at a fixed set point would be to operate the supply fans. The thermostats would control the dampers and the low limits would prevent the supply air temperature dropping below +5°C. This would prevent the space temperature rising and the possibility of the exhaust fans starting. However, this method uses more power than the first method outlined.

Secondary pumps should be chosen for parallel operation giving more flow reliability in the event of an unmanned failure.

4.0 WASTE HEAT MARKET

4.1 POTENTIAL CONSUMERS

In order for a district heating and waste heat recovery system to be viable, there must be an adequate market for the heat. Ideally, the potential consumers should be close to the source of heat to avoid long and expensive piping runs that may lose a lot of heat. As well, the ideal customers should have a relatively large, single point heat demand that is currently met using fuel oil. Institutional, commercial and government-owned structures will generally be primary consumers as they will be the building owners most likely to meet these criteria.

In reviewing the potential consumers, a long list was assembled. Some candidates for service that may be appropriate in Wollaston may not be serviceable in other locations. The size of the structure, the existing heating system, the method of operation, and the distance from the source will all impact the viability of supplying heat to the structures in question.

The following is a list of potential consumers of waste heat from the generating facilities. They are ordered, in general, from first priority to last, although this will vary from community to community. The discussion under each facility relates only to Wollaston.

1. Generating Facilities:

   Clearly, the heating demand of the generator building and ancillary buildings should be satisfied before considering supplying heat to any other structures. Most of the heat for the generator building can theoretically be supplied by radiation from the diesel engine and generator heat emissions. The ancillary generator building facilities at Wollaston have a low demand and can readily be served.

However, the proposed operating philosophy of the generating facility, with allowance of large volumes of makeup air being drawn into the building when an exhaust fan is switched on, would place an extremely high demand on the available waste heat. A different operating philosophy is required to prevent this large demand from occurring, thereby, making the heat available to the market place.

2. School:

It is been the intention of the Northern Lights School Division to have a single storey school constructed approximately 1000 metres from the new power generation station on the east side of Welcome Bay.

The new school which has not received government notice to proceed, has been estimated to have an area of 2973 m^2. The school is expected to be comprised of classrooms, workshops, a laboratory and a gymnasium.

The school will be a major potential consumer of waste heat. It would normally be a large consumer of fuel oil, and as a government institution, risk of non-payment or maintenance of the equipment is small. The major disadvantage to servicing the school is its distance of about 1000 metres from the generating facilities. Most previous studies and actual installations of waste heat recovery systems have had the major user very close to the generating station. For example, the buildings at Oxford House and Attawapikat were only 30 metres from the generating station and at Lac La Martre, 100 metres. Consequently, the length of service pipes involved is a large issue in assessing the viability of district heating at Wollaston Lake.

3. Community Water System:

Most northern utilities find it necessary to heat and circulate their water supply systems to prevent freezing. This can be a fairly large oil consumption. Consequently, community water systems are excellent potential waste heat consumers. Generally, there is little risk of maintenance problems. Risk of payment or vandalism of facilities is also usually low.

4. Health Clinic:

There is a new health clinic located near the school. The health clinic also meets all the criteria for a potential consumer, although the total demand for the building will not be great.

5. Institutional Residences:

Institutional residences are also excellent potential consumers. Institutional residences would include teacherages, nurse residences, RCMP residences, and church rectories. It is assumed that there will be teacherages associated with the school. Teacherages and other institutional buildings are considered good potential consumers since they are usually oil heated, not subject to vandalism, well maintained and risk of non-payment for heat consumption is small. However, there is little potential for these consumers in Wollaston due to the existing facilities being on the west side of Welcome Bay.

6. Commercial/Industrial/Institutional:

Various commercial, industrial and other institutional users can be good potential candidates. They can be large consumers of fuel oil and could meet the other criteria outlined. However, in Wollaston the potential commercial and industrial users are generally located

on the west side of the bay and consequently, have been considered to be outside the service area. (Potential consumers would be the Hudson Bay Store and residence, Government Services buildings, the church and other structures located in the community core area.) Other candidates for service include arena and recreational buildings, meeting halls, band offices, Local Advisory Committee offices, and fish processing facilities, along with other commercial, industrial and institutional buildings. If commercial enterprises were to locate on the east side of the bay adjacent to the generating station, economic servicing might result. With the exception of a laundromat, servicing of existing or potential commercial facilities has not been considered.

7. Residential:

In general, small residential demands are the least economic structures to service. They are a small load but require much of the same costs to service as a single, much larger consumer of heat. Each structure requires service pipes, a heat meter, a pump, and a heat exchanger. Consequently, large point loads are much more economical to serve than single family residences. In addition, all of the housing on reserve land is currently served by wood stoves so serving them would not offset oil currently being used. Additionally, the residents are frequently away from their homes which could leave the system vulnerable from the point of view of maintenance and vandalism. However, if some fulltime winter residents wished to be connected after a system was in operation, if surplus heat was available to serve them, and the economics justify service, then service could be supplied to individual residences.

8. Laundromat:

A laundromat was considered because it is a needed community facility that not only has a winter heat demand for building heat but also a year around heat demand for hot water. Although it is likely that hot water heating would have to be supplemented by oil heat, considerable savings may be realized by using the available waste heat from the generating facilities. The laundromat could be located anywhere along the route of the heat supply piping. However, it would be better located close to the generating station to limit the distribution losses during the summer. The school will have a water demand which could use generator waste heat during the summer. If the system is run to service the school, the location of the laundromat is not critical. If only the laundromat is served during the summer, it would be better located close to the generating station and served with the proposed distribution system or served separately with its own circuit.

9. Summertime Heat Users:

Most of the users identified above have primarily been for winter time space heating. There will also be heat available in the summer. This heat could be used for heating a greenhouse, subsurface soil heating, to heat the soil in garden plots to extend the growing season, or to heat water for an outdoor swimming pool.

The amount of waste heat available in summer has not been analysed. The analysis of greenhousing and soil heating, the problems, costs and benefits is too complex to be included in this study. Swimming pool heating may be viable if a district heating system exists but this also was considered beyond the scope of this study.

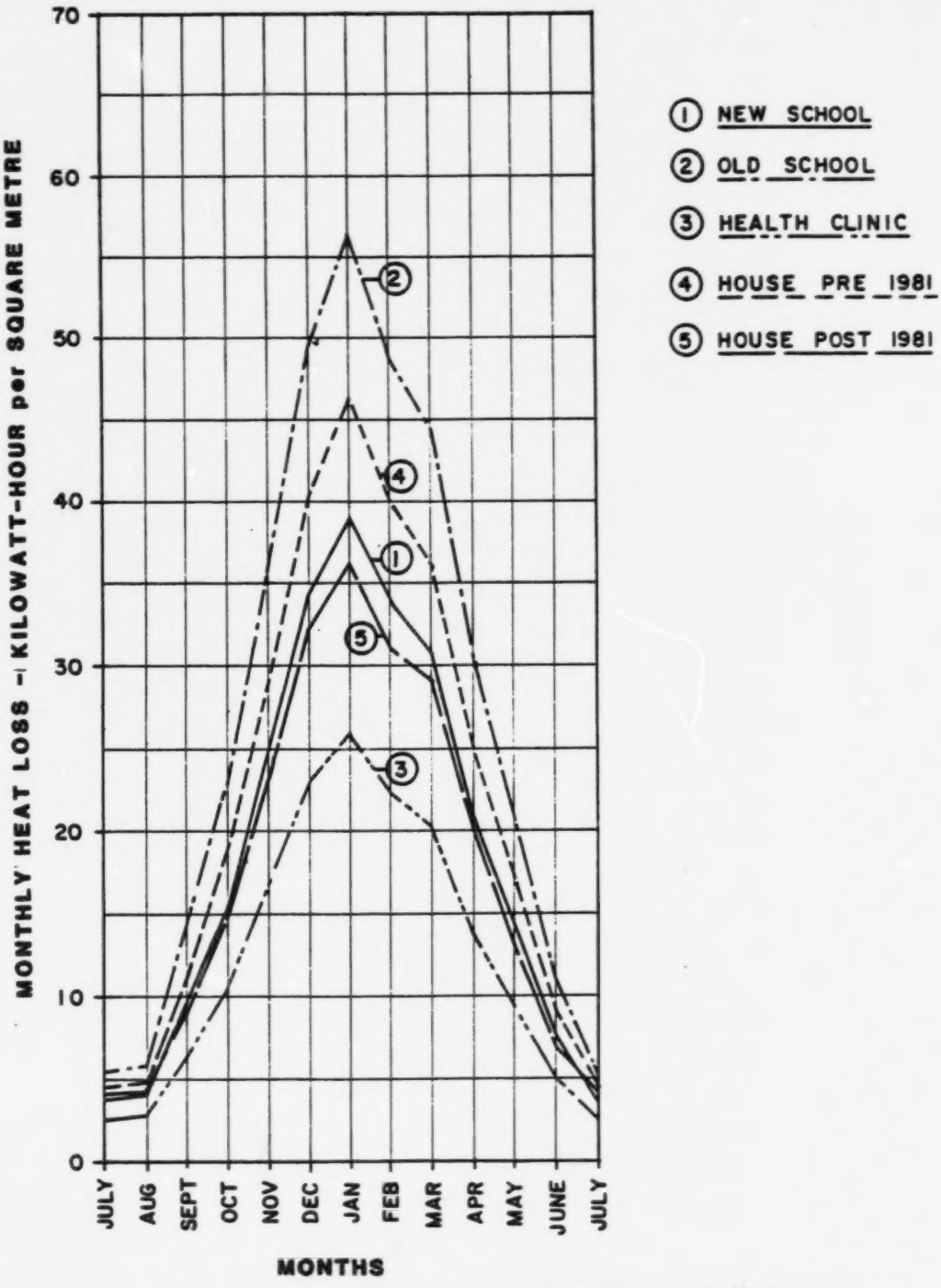
4.2 HEATING REQUIREMENTS

In order to assess the viability of the concept, it was necessary to determine how much heat would be required by various types of facilities and the amount of heat that might be available to supply them.

The available heat was considered to be proportional to the electrical demand. This was analysed in the previous section and a relationship established.

In examining the heat demand, typical buildings were reviewed to establish unit heat losses for various building types. This is shown on Figure 10. Nominal infiltration losses and ventilation rates have been assumed and are listed in Appendix A. By conducting the heat losses on a unit area basis, similar buildings could readily be analysed. This graph, in combination with others, will allow transference of results in Wollaston to other communities. The design parameters for the buildings are listed in Appendix A.

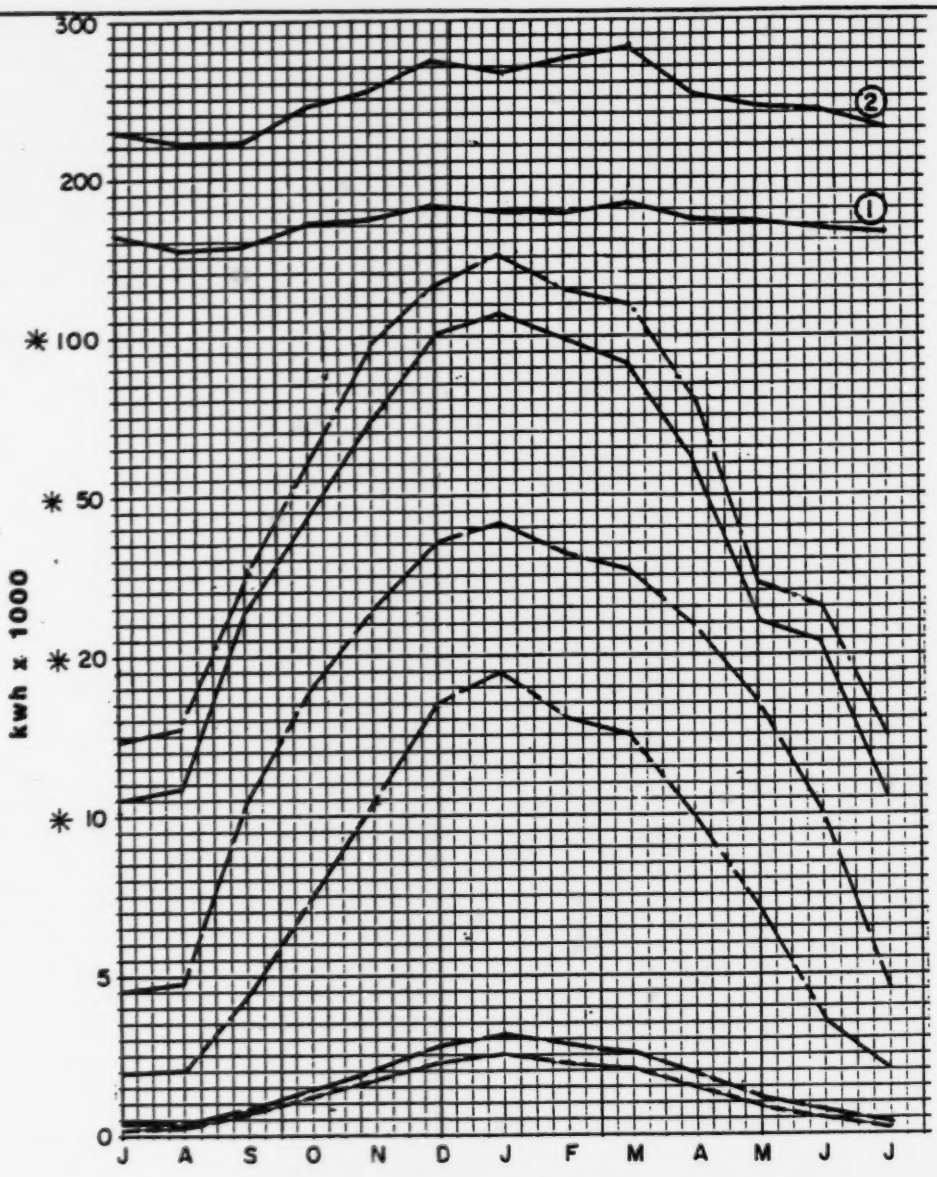
The annual heat consumptions shown on Figures 11, 12 and 13 indicates the total annual and average building consumptions based on degree day figures for annual and average winter conditions for Brochet, Manitoba. This data forms the basis for all subsequent heat demand figures used in this report for building heating requirements. The monthly temperatures and degree day values are listed in Appendix A. In addition to individual building heat requirements, we have combined a number of them and plotted generator heat output on these figures. This gives some indication of how many facilities could be served. These graphs clearly show that there is adequate heat to meet the mean heating requirements of several facilities with the mean heat produced by the engine off the water jacket.



UNIT AREA HEAT LOSSES for VARIOUS BUILDINGS

CLIENT/PROJECT SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
	DATE
	JOB No RJ65 — FIG. 10

BCIL 3590A - AES

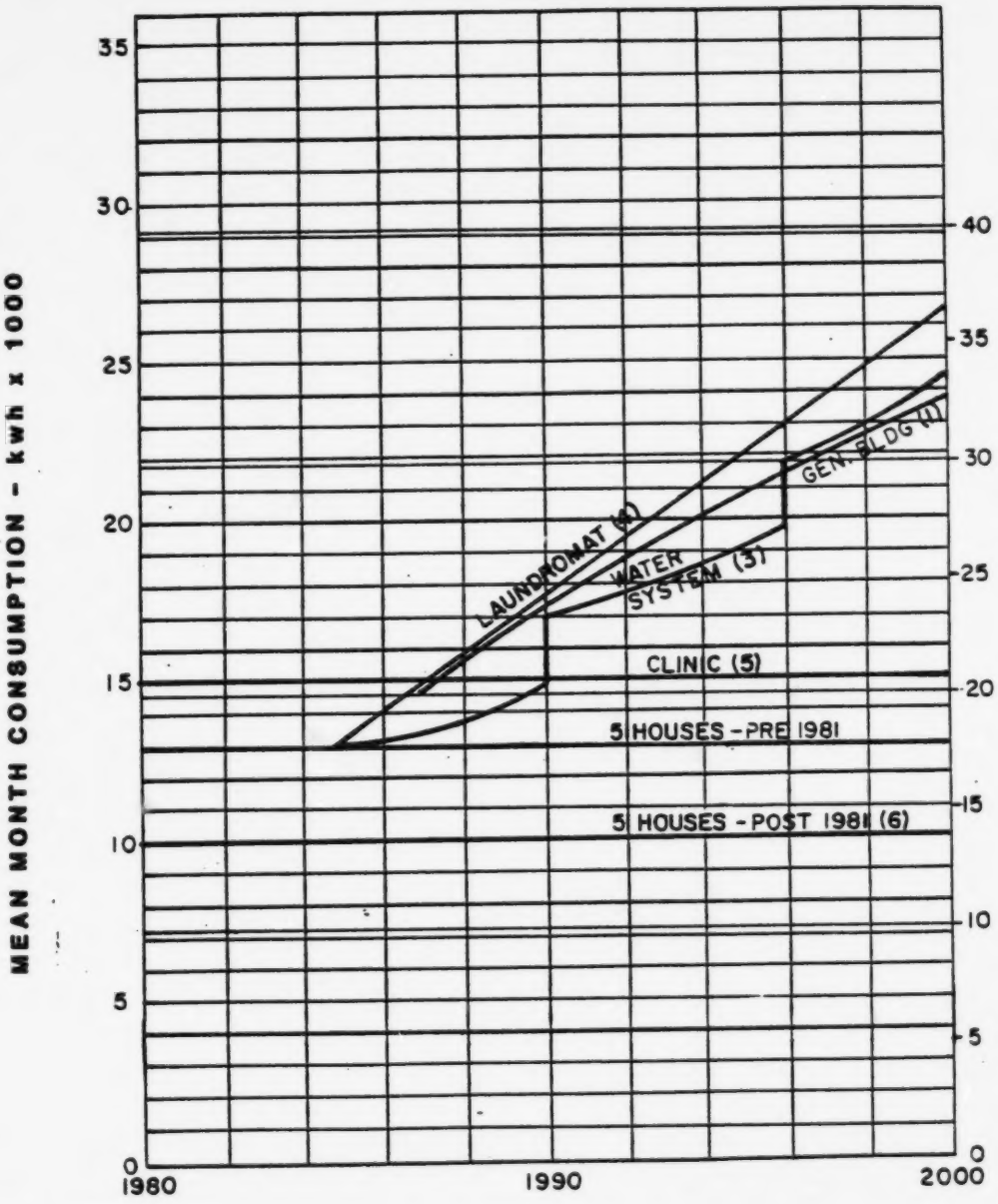


NOTE:
- SUM EQUALS TOTAL HEAT CONSUMPTION FOR THE NEW SCHOOL, HEALTH CLINIC AND POST 1981 HOUSES (5).
- VERT. SCALE CHANGES AT THE POINTS DENOTED THUS *

SUM
NEW SCHOOL - 2973 m²
OLD SCHOOL - 813 m²
HEALTH CLINIC - 732 m²
PRE 1981 HOUSE - 71 m²
POST 1981 HOUSE - 71 m²
① RECOVERABLE WATER JACKET HEAT
② TOTAL RECOVERABLE HEAT

ANNUAL HEAT DEMAND AND GENERATOR OUTPUT

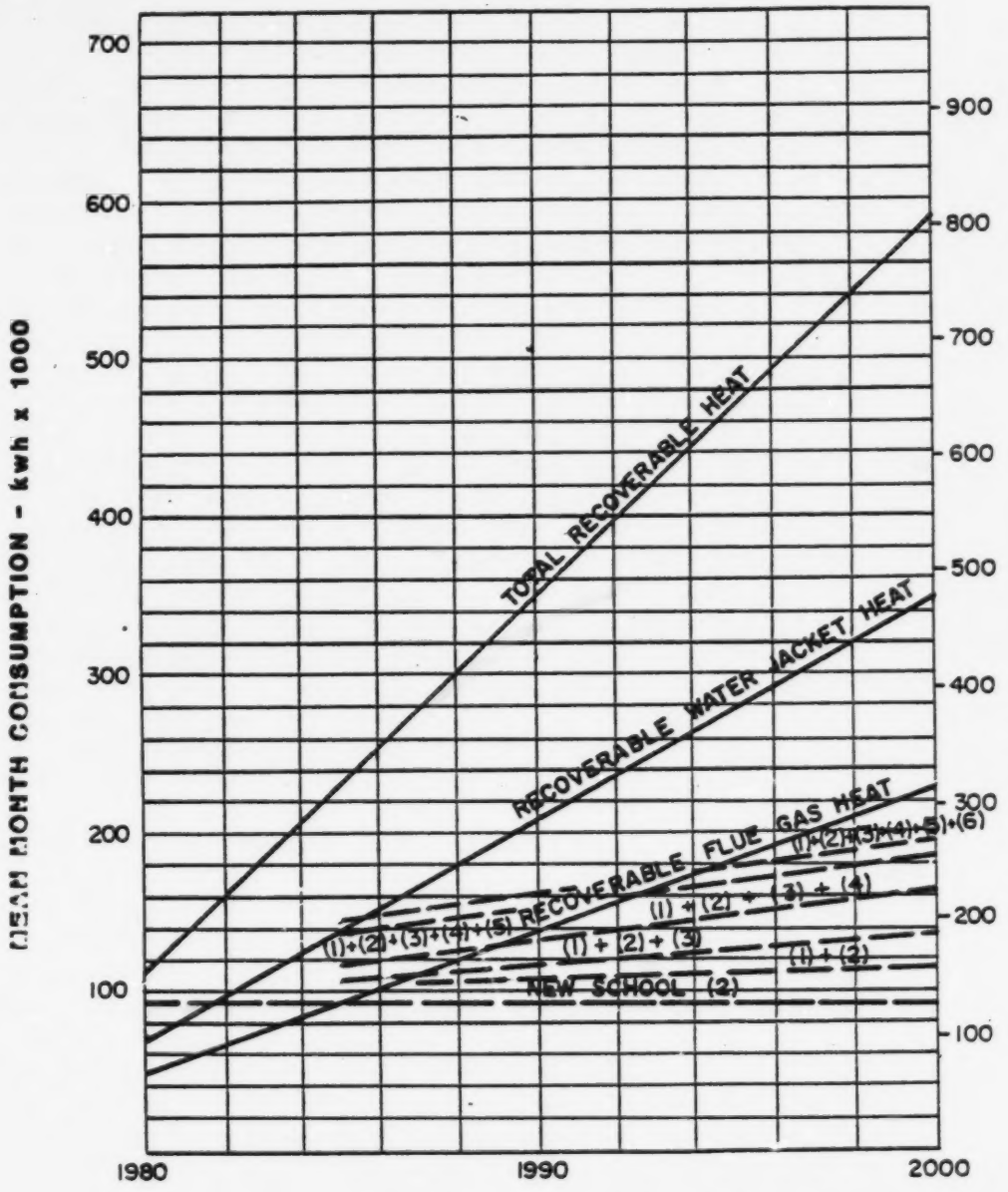
CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
	DATE / DWG No **FIG. 11**
	JOB No.



MEAN MONTHLY HEAT CONSUMPTION

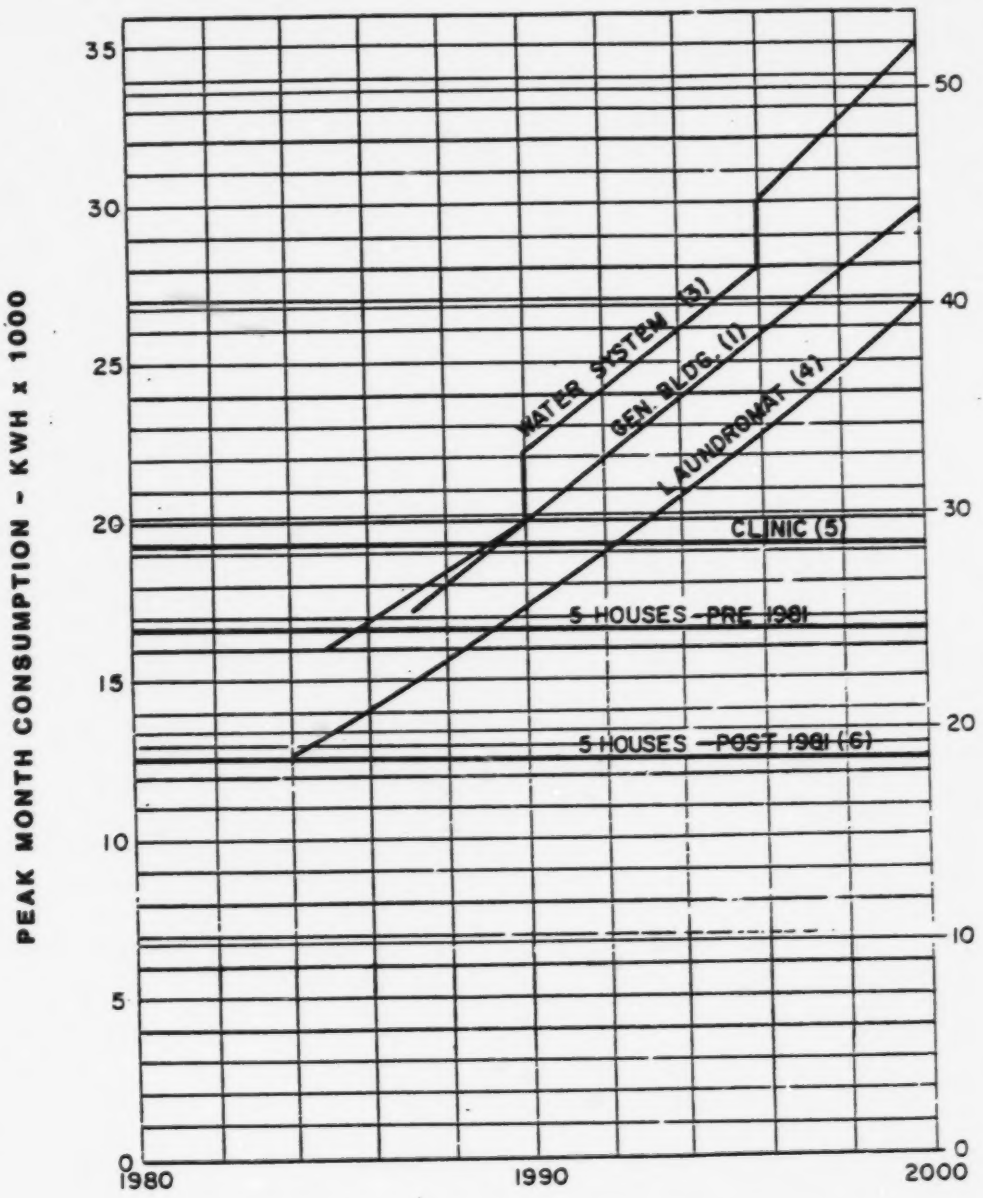
FOR VARIOUS BUILDINGS

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
	DATE / DWG No. FIG. 12A
	JOB No.



MEAN MONTHLY HEAT CONSUMPTION FOR VARIOUS BUILDINGS AND RECOVERABLE HEAT FROM ENGINE

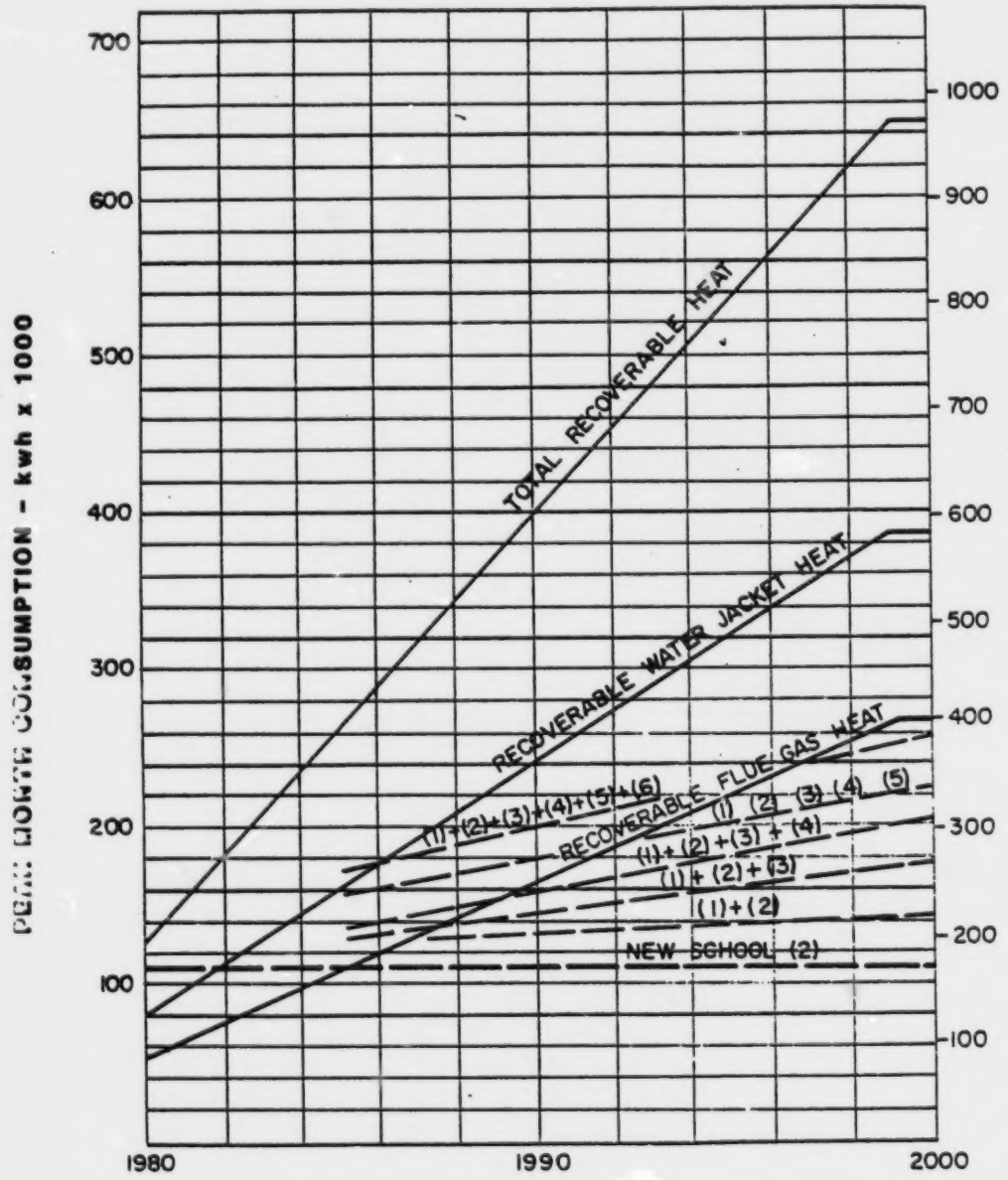
CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
AESL	DATE / DWG No. **FIG. 12B**
	JOB No.



PEAK MONTHLY HEAT CONSUMPTION

FOR VARIOUS BUILDINGS

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD. AESL	APPROVED / SCALE
	DATE / DWG No. FIG. 13A
	JOB No.



PEAK MONTHLY HEAT CONSUMPTION FOR VARIOUS BUILDINGS AND RECOVERABLE HEAT FROM ENGINE

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / DATE / JOB No. / SCALE / DWG No. FIG. 13B

However, heat demand for some facilities varies with time. For example, the water system will have more flow in it as the population increases and will undergo several expansions which will result in discrete jumps in demand. Similarly, the laundromat will undergo a gradual increase in demand as more people use the facility.

Concurrently, the electrical demand will increase, resulting in more heat being available.

Figure 11 shows only mean heat demand for fixed building demands and generator output in 1985. If the system can supply only the mean heat requirements for a given month then supplemental heating will be required for peak month, peak day and peak hour demands. In order to assess these criteria and variation with time, Figures 12a, 12b, 13a and 13b prepared. These figures show various combinations of heat demand and estimated available heat from the generator for various years for flue gas, water jacket, and flue gas and water jacket recovery for the six mean winter months of October, November, December, January, February and March, for the mean winter demands (Fig. 12) and the peak month demands (Fig. 13).

As indicated on the graphs, all of the mean month heating requirements can be met by water jacket heat recovery. The water jacket can also supply the peak month loadings.

However, these graphs do not take into account the coincidence of heating requirements and available heat. If peak power supply and peak heating demand are not coincidental, there will be times when there is a large surplus of heat, over demand, that cannot be used, and other times that there is a greater demand than supply which will require supplemental heating. There is inadequate data to determine a coincidence factor. This will be discussed further in the next section of this report.

These figures do not account for delivery system losses.

It also needs to be said that while there appears to be adequate heat to supply a number of structures, flue gas heat recovery costs, the piping delivery system costs, customer equipment operation and maintenance costs, payback period, value of saved fuel oil, and other economic factors will determine the viability of the project.

4.3 HEAT SYSTEM CONCEPTS

In order to develop costs for the system, it was necessary to develop concepts for transferring heat from the engine to the fluid medium, for the delivery system, and for transfer from the delivery system to the users' system.

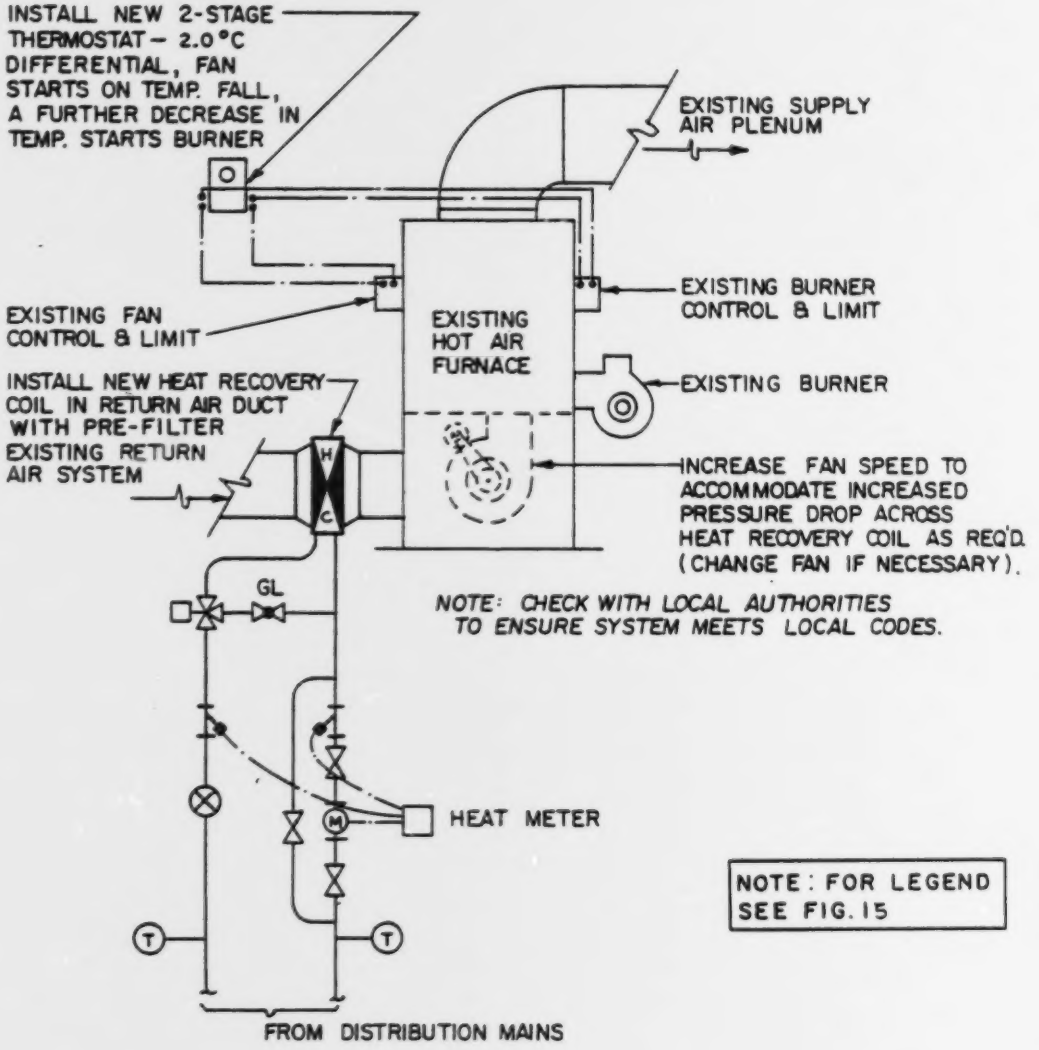
The concepts for heat recovery off the engine have been described in the previous section on Available Waste Heat. The delivery system will be discussed in more detail in the following section on Deliverable Waste Heat.

The user system concepts are described as follows:

1. Small Structure Heating System:

   A typical system for providing heat to a small building such as a home, the health clinic or other commercial enterprises is shown on Figure 14.

   A new heat recovery coil would be installed in the return air duct sized to deliver the system heat requirement (not necessarily the output of the furnace as furnaces are normally oversized).


INSTALL NEW 2-STAGE THERMOSTAT – 2.0°C DIFFERENTIAL, FAN STARTS ON TEMP. FALL, A FURTHER DECREASE IN TEMP. STARTS BURNER
EXISTING SUPPLY AIR PLENUM
EXISTING BURNER CONTROL & LIMIT
EXISTING FAN CONTROL & LIMIT
EXISTING HOT AIR FURNACE
EXISTING BURNER
INSTALL NEW HEAT RECOVERY COIL IN RETURN AIR DUCT WITH PRE-FILTER
EXISTING RETURN AIR SYSTEM
H
C
INCREASE FAN SPEED TO ACCOMMODATE INCREASED PRESSURE DROP ACROSS HEAT RECOVERY COIL AS REQ'D. (CHANGE FAN IF NECESSARY).
GL
NOTE: CHECK WITH LOCAL AUTHORITIES TO ENSURE SYSTEM MEETS LOCAL CODES.
M
HEAT METER
T
T
FROM DISTRIBUTION MAINS

NOTE: FOR LEGEND SEE FIG. 15

TYPICAL CLINIC OR HOUSE

HEATING SYSTEM

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
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	DATE / DWG No FIG. 14
	JOB No.

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A two-stage thermostat would, on the first stage, start the fan if it is not operating and modulate a three-port bypass mixing valve on the return line from the distribution mains. If this coil could not meet the demand of the building or zone served, the second stage would start the oil burner.

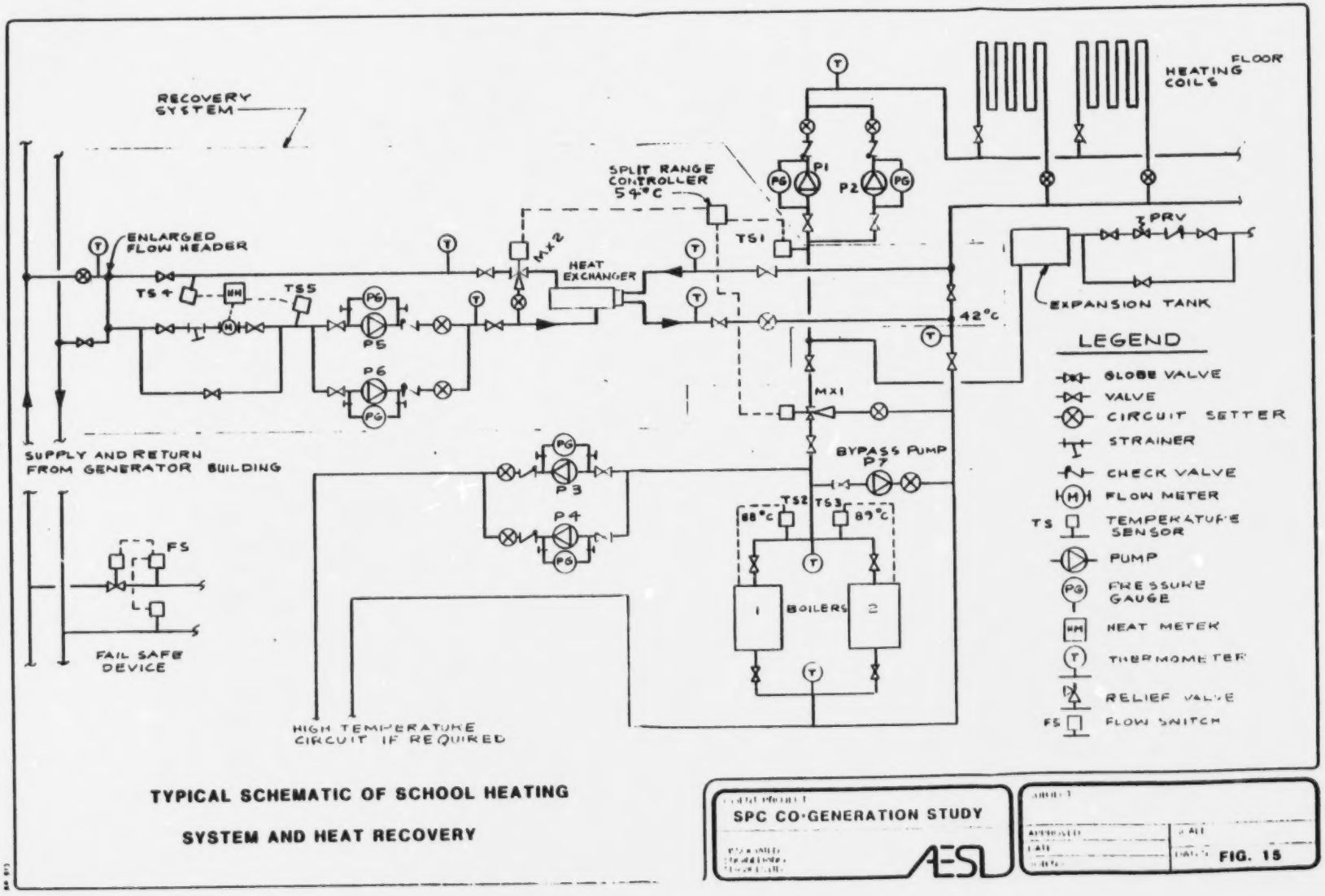
The addition of a preheat coil will increase the air flow resistance of the existing system. To maintain the same volume of air circulation or at least the minimum persmissible for the furnace, the fan speed will have to be increased. New furnace equipment should not be required unless the ductwork system connected to the unit has a high resistance and the fan is operating close to its volume/pressure limitations.

A heat meter recording supply and return temperatures and the flow circulating from the main distribution pipes is required.

Where single homes are served, the supply and return pipes would rely on the pressure differences across the mains to produce flow. Where several homes or system are served, a circulating pump would draw liquid from a circulating loop and return it to the distribution return main.

2. School:

Figure 15 shows the piping schematic for the school heat generating equipment and recovery heat exchanger. Because of the low temperature requirement for floor heating panels (54°C flow), it is recommended that this type of heating be used throughout the school wherever possible. This lower temperature water is attainable with the primary heat supplied from the generator. The low temperature water can be used for air heating but coil sizes and air volumes will be greater than would be required with higher temperature water (88°C). If this is not acceptable in the final design of the



TYPICAL SCHEMATIC OF SCHOOL HEATING SYSTEM AND HEAT RECOVERY

SPC CO-GENERATION STUDY

AESL

FIG. 15

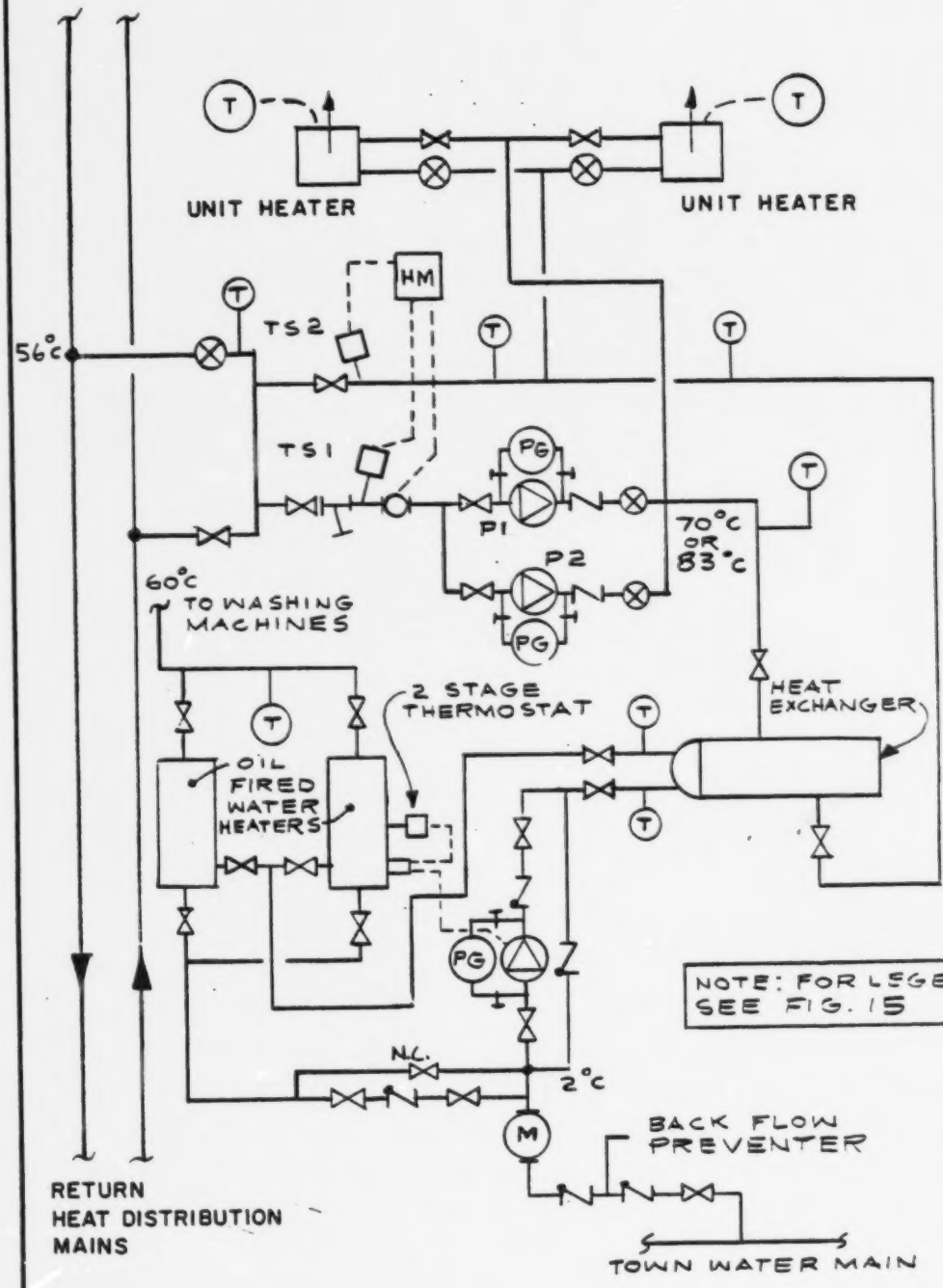
school, higher temperature water from the boilers can be used. The school system would be served by two oil-fired boilers operating between 88°C and 93°C.

The low temperature pumps, P1 and P2, would circulate water to the floor coils. The temperature of the supply water would be controlled by a three-port mixing valve, MX1, in series with the bypass mixing valve, MX2, on the primary circuit to the heat exchanger.

On a demand for heat, temperature sensor TS1 would modulate MX2 to control at a set point. When MX2 is fully open to flow through the heat exchanger and the flow temperature continues to fall, sensor TS1 will modulate MX1 to maintain a set point temperature, the heat exchanger being in series with MX1 and/or the boiler. As load decreases, MX1 will close to the boiler water and MX2 will take over control modulation. Because the return water temperature from a floor heating system is too low to be pumped into the boiler, a bypass pump is needed to circulate hot water from the boiler header into the return to elevate the return temperature to an acceptable 78°C to 80°C. Low return water temperatures will cause thermal stressing of the boilers and condensation and corrosion in the flue system.

Circulating pumps P5 and P6 draw glycol from a circulating flow header on the distribution mains through a heat meter flow meter and deliver it to the heat exchanger or bypass it to return to the header and from there to the return main to the generating building.

Because the pressure differential across the primary connections on the flow header is small, pumps P5 and P6 will be unaffected by the pressure differential across the main distribution flow and return connections.



TYPICAL SCHEMATIC FOR LAUNDROMAT HEATING

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3. Laundromat:

The laundromat heat system is similar to the previously described small buildings heat system except that a circuit has been added for pre-heating the water for washing. The concept is shown on Figure 16. Depending on the water flow, the heat exchanger may not be able to heat the water up to wash temperatures.

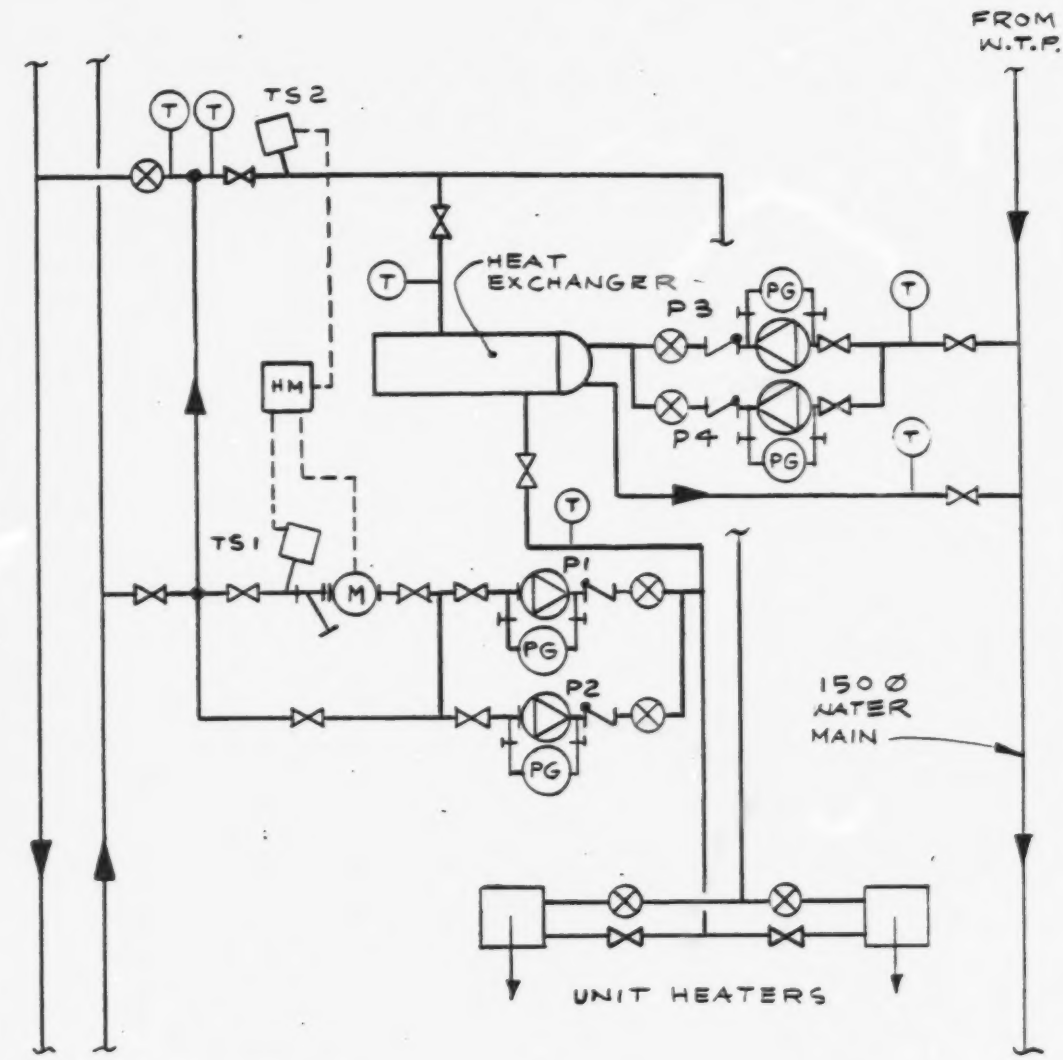
The concept allows for all the water heat to come from the heat exchanger for low laundromat demand conditions by re-circulating the water through the heat exchanger when the temperature is below a specified level. At higher laundromat demand, the heat exchanger may provide only pre-heating.

The heat exchanger may be fed with a circulating pump or directly from the community water supply. The concept also allows for the heat exchanger to be isolated from the water heating loop.

A number of alternatives are possible and would have to be examined in detail during design for a laundromat.

4. Water System:

All northern water systems require heating of some kind and are usually circulated. The concept shown on Figure 17 provides one method of inputing heat to a community water distribution system. Ideally, this heat input would be to both the incoming raw water to pre-heat the water prior to treatment, and the treated water going out of the water treatment plant. Consequently, the best location for the heating unit would be at the community water treatment plant. This would allow the water treatment plant to be heated from the waste heat as well. Unfortunately, the community layout in Wollaston is such that it appears to preclude the facility being located in the future water treatment plant. A remote site to heat



NOTE: FOR LEGEND SEE FIG. 15

TYPICAL SCHEMATIC FOR

WATER SYSTEM HEATING

CLIENT/PROJECT **SPC CO·GENERATION STUDY**	SUBJECT
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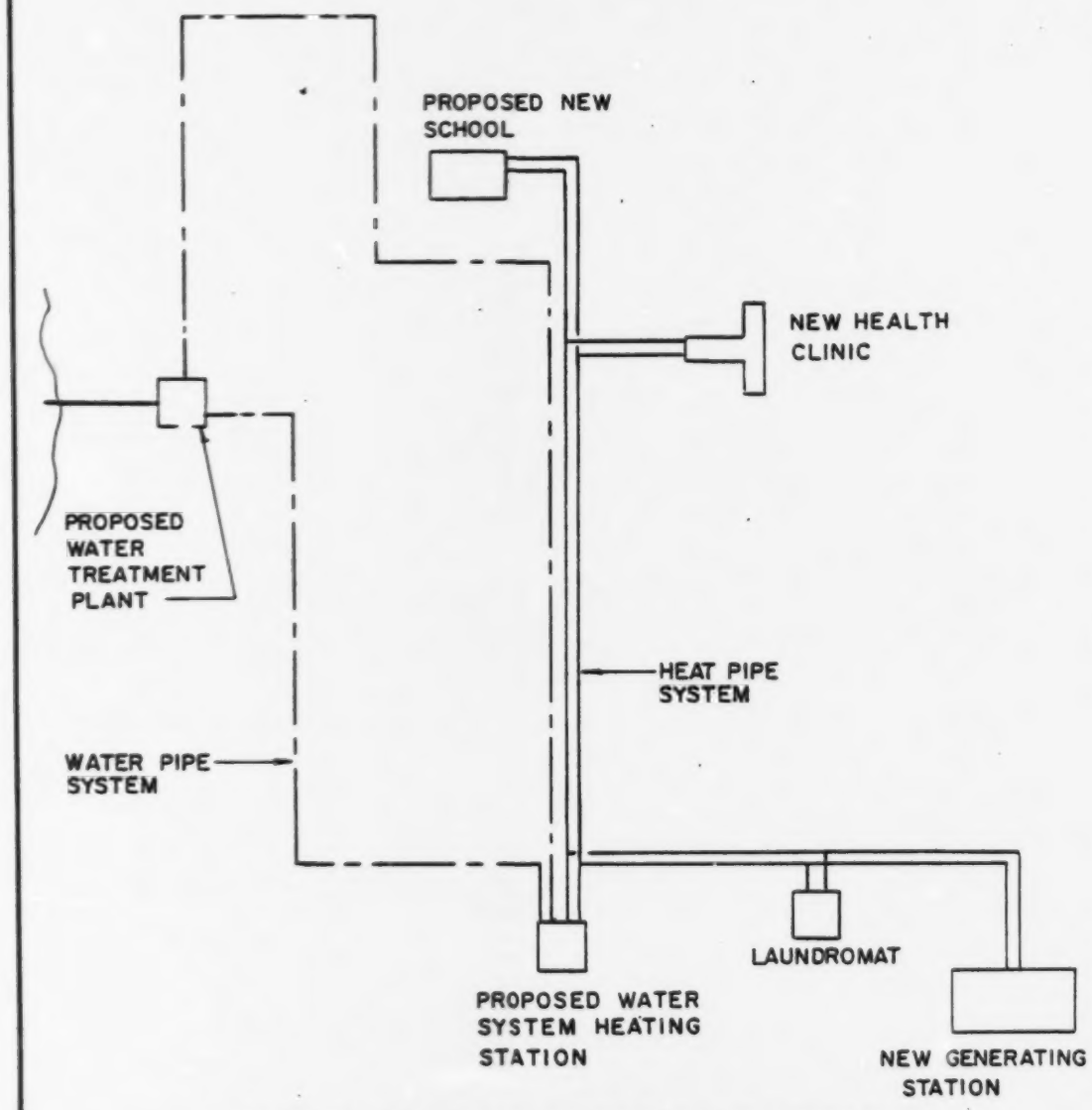

WATER HEATING SYSTEM SCHEMATIC

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
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one of the circulating loops that will supply the school water system has been shown on Figure 18. The costing has been based on a separate prefabricated structure to house the heat exchanger, heated with waste heat. However, this facility could just as readily be housed in a partitioned-off room in the new school or any other public building with a separate outside entrance for water maintenance personnel.

The concept is relatively simple. When water main temperatures begin to drop, the pumps are turned on to circulate water from the town system through the heat exchanger. Presumably, the pumps for the heat distribution system will have been operating already to provide heat to the building unit heater(s).

The heat exchanger will then supply heat to the circulating water main. This main will carry the water back to the reservoir at the water treatment plant where it will impart its heat to the cooler reservoir water. This water will, in turn, be pumped back into the distribution system. Water in the heated loop will continue to receive heat, and water in other loops will be heated by virtue of the warm water being returned to the system reservoir. The reservoir water will provide an excellent heat sink and a considerable safety factor on freeze protection if the loop heating system is appropriately sized.

It should be noted that mechanical "failsafe" provisions have not been provided for in any of the above systems. Should a piping failure occur on the primary side of any building system that is hooked directly to the heat distribution system, it will cause the entire system to fail due to the closed nature of the system. This has to be considered when selecting customers for the system. It was one of the considerations made in selecting a glycol-water solution as the fluid medium. Loss of pressure will not result in system freezeup, resultant

pipe damage, and lengthy system downtime due to repair. One system shutdown and freezeup could offset the extra cost of the glycol solution alternative.

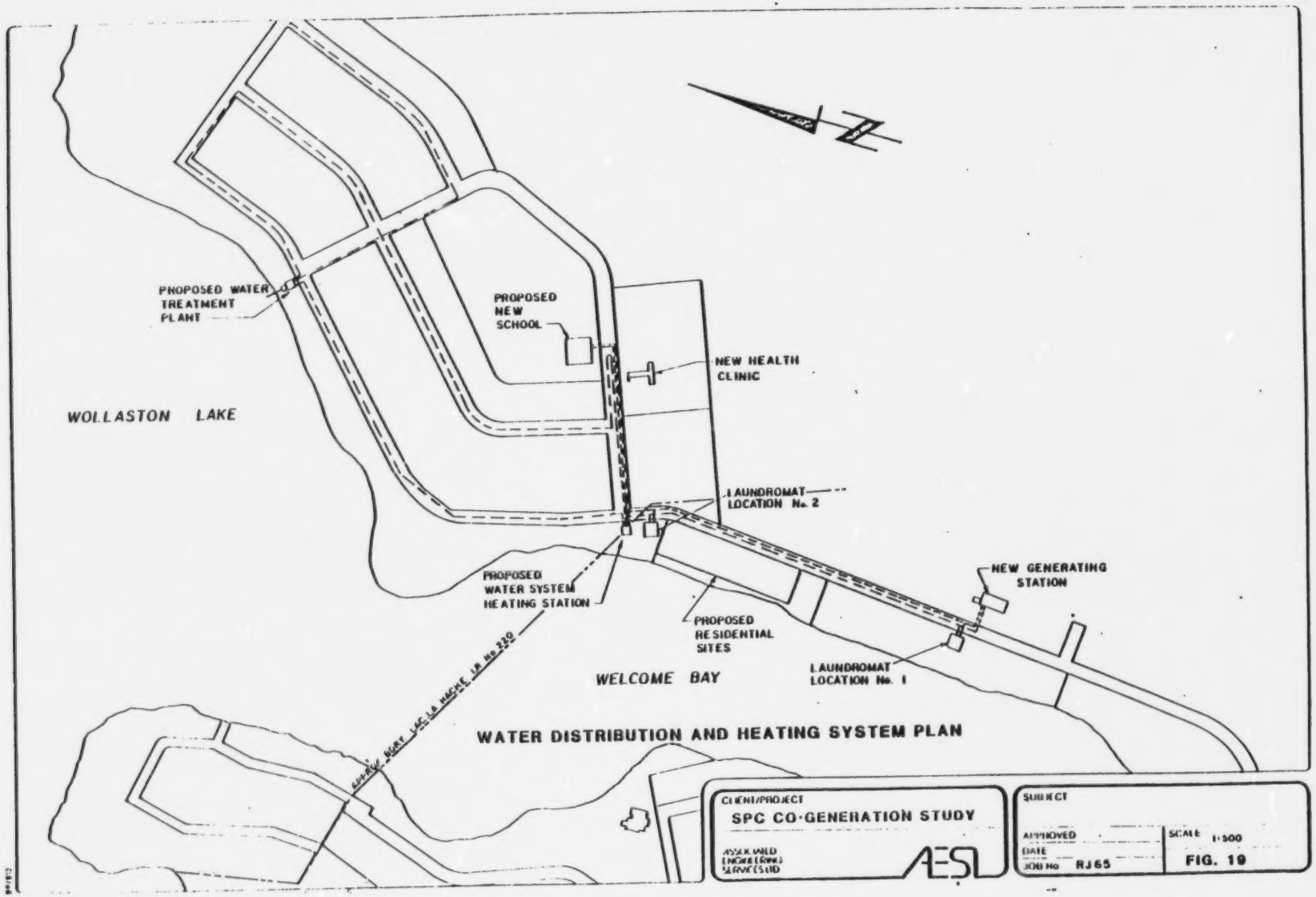
However, the solution is costly and a system shutdown could be costly. When evaluating the configuration of consumers' heating devices and when examining consumers, the need for mechanical failsafe devices to prevent solution loss within a particular consumer's structure may have to be considered. Such a device could consist of a flow swtich or pressure switch and solenoid valves at the point of entry to the customer's premises. If a flow reversal on the return line or an abnormal pressure drop occurred, solenoid valves could be automatically triggered, isolating the customer's system from the supply system, thereby, preventing a major fluid loss. A failsafe device is illustrated on Figure 15.

As shown by the foregoing, there appears to be a market for the waste heat. Waste heat appears to be available in sufficient quantity to supply a number of potential customers. Equipment can be supplied to take heat off the diesel engines, deliver it to users, and transfer that heat to the users.

One issue that has not been addressed is the lower temperature that heat would be delivered at with a waste heat system rather than an oil or propane fired system. Many people find that it takes some time to get used to radiant heat or lower temperature heat supply systems. This is due to their being used to high temperature exhaust from their air supply ducts when the furnace is operating. Other systems cycle less often. They run longer or continuously at a lower temperature output. Once people become acclimatized to the system, the problem disappears.

The main question that now must be answered is whether or not the available waste heat can be delivered economically. This will be dependent on the amount of waste heat generated that is deliverable, the cost of supplying the heat, and the potential for payback. The following section deals with delivery system losses and other factors that will affect the amount of waste heat actually available to the consumer.

The proposed layout of the heat delivery system, showing the relationship between the school, the water system, and the community is shown on Figure 19.


PROPOSED WATER TREATMENT PLANT
PROPOSED NEW SCHOOL
NEW HEALTH CLINIC
WOLLASTON LAKE
LAUNDROMAT LOCATION No. 2
NEW GENERATING STATION
PROPOSED WATER SYSTEM HEATING STATION
PROPOSED RESIDENTIAL SITES
WELCOME BAY
LAUNDROMAT LOCATION No. 1
WATER DISTRIBUTION AND HEATING SYSTEM PLAN
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SCALE 1:500
FIG. 19

5.0 DELIVERABLE WASTE HEAT

The amount of heat generated by the diesel engine and the amount of heat that is deliverable to the consumer on demand will vary significantly. There are five major items that impact the amount of heat that will be available to the consumer. These five items are:

1. Efficiency of recovering heat from the diesel engines;
2. Heat losses from the piping system;
3. Heat transfer efficiency of users' equipment;
4. Coincidence of daily power supply to heating requirements; and
5. Coincidence of heat supply and demand.

5.1 EFFICIENCY OF RECOVERING HEAT FROM THE DIESEL ENGINES

The diesel engine generator manufacturers provide tables giving the thermal balance of the engine generator set at a number of different loads. These are shown on Figure 5.

The heat rejected to the water jacket is almost all recoverable with the correct selection of heat exchanger equipment and the choice of secondary flow and return temperatures. The maximum rejected heat is 570 kW at full load.

Not all the heat rejected to the exhaust gas is recoverable because of the need to maintain a minimum discharge gas temperature of 163°C. The maximum heat recoverable from the exhaust gas at full load is 400 kW or 62% of the heat available.

The basic heat exchanger costs for exhaust gas heat recovery is approximately 6 times more expensive per kilowatt recovered than for engine water jacket heat recovery. This has a significant bearing on the economic viability of flue gas heat recovery. This is discussed further in the section on Economics Analysis.

5.2 HEAT LOSSES FROM THE PIPING SYSTEM

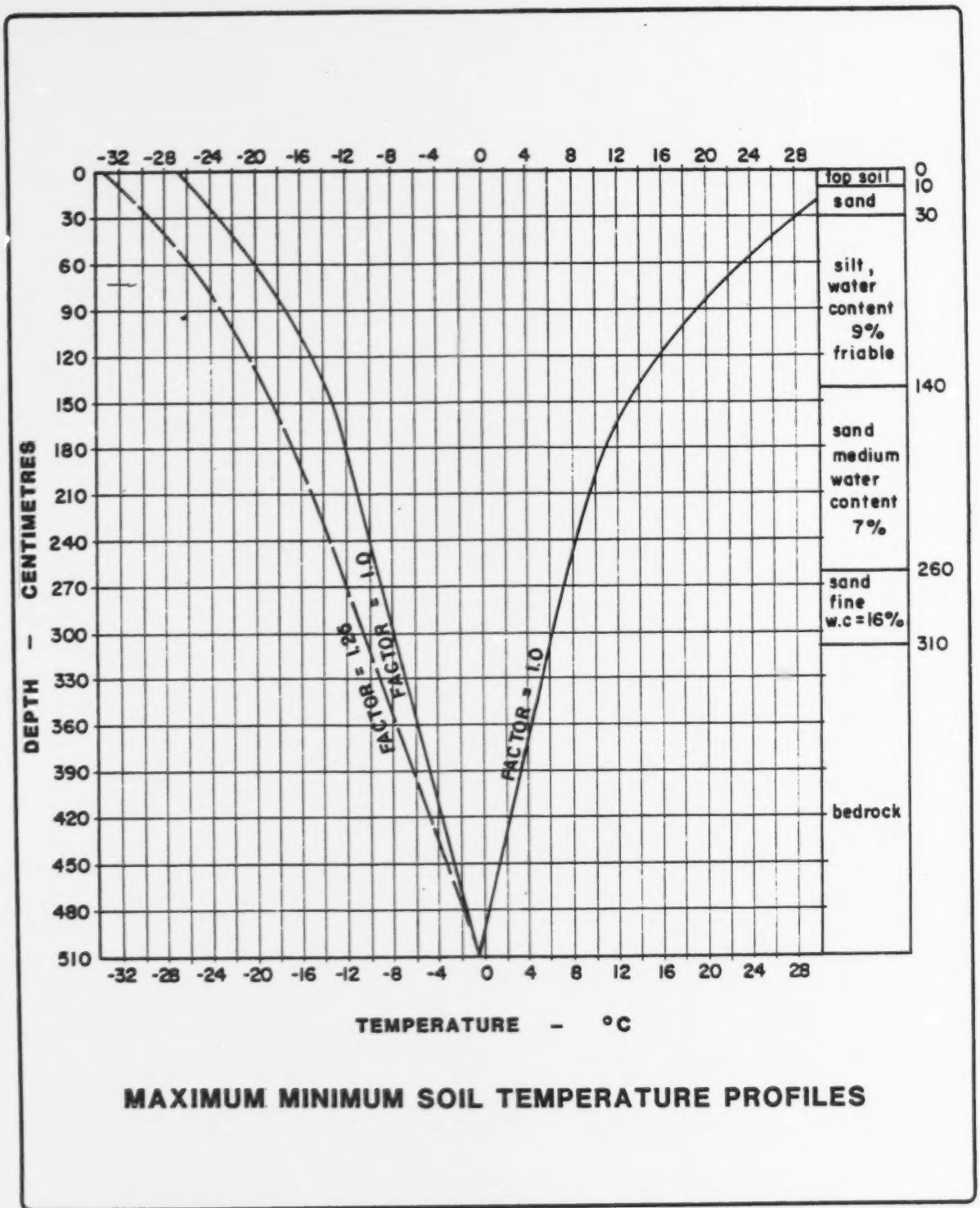
Major heat losses will occur in the piped delivery system. The piping system selected should be the one that minimizes the net cost and maximizes the deliverable waste heat.

Exposed piping systems are subject to mechanical damage as well as high heat losses. Consequently, it is desirable to bury the piping system. A number of different piping systems are available. They will be discussed in detail in section 7.2. The basic criteria relating to heat loss will be depth of bury (soil temperature) and insulation thickness.

The first step in this analysis was to determine the approximate soil temperature profiles for the Wollaston Lake area. Soil log information was obtained for the community along with air temperature data from Brochet, Manitoba. This data was run through a computer simulation program, "Temps", to develop soil temperature profiles. A more detailed explanation of the program and a sample output is contained in Appendix H.

The results of this analysis are shown on Figures 20, 21 and 22. Figure 20 is a soil temperature envelope that shows the minimum and maximum expected temperature variations with depth. This graph is based on permafrost existing at a depth of about 5 metres. This is consistant with the available geotechnical information and climate.

This figure shows the wide temperature fluctuations that are expected near ground surface; a rapid decrease in variation down to about 1.5 metres, with a relatively linear decrease in variation from 1.8 to 5 metres where the temperature was held constant.



MAXIMUM MINIMUM SOIL TEMPERATURE PROFILES

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AES	SCALE: FIG. 20

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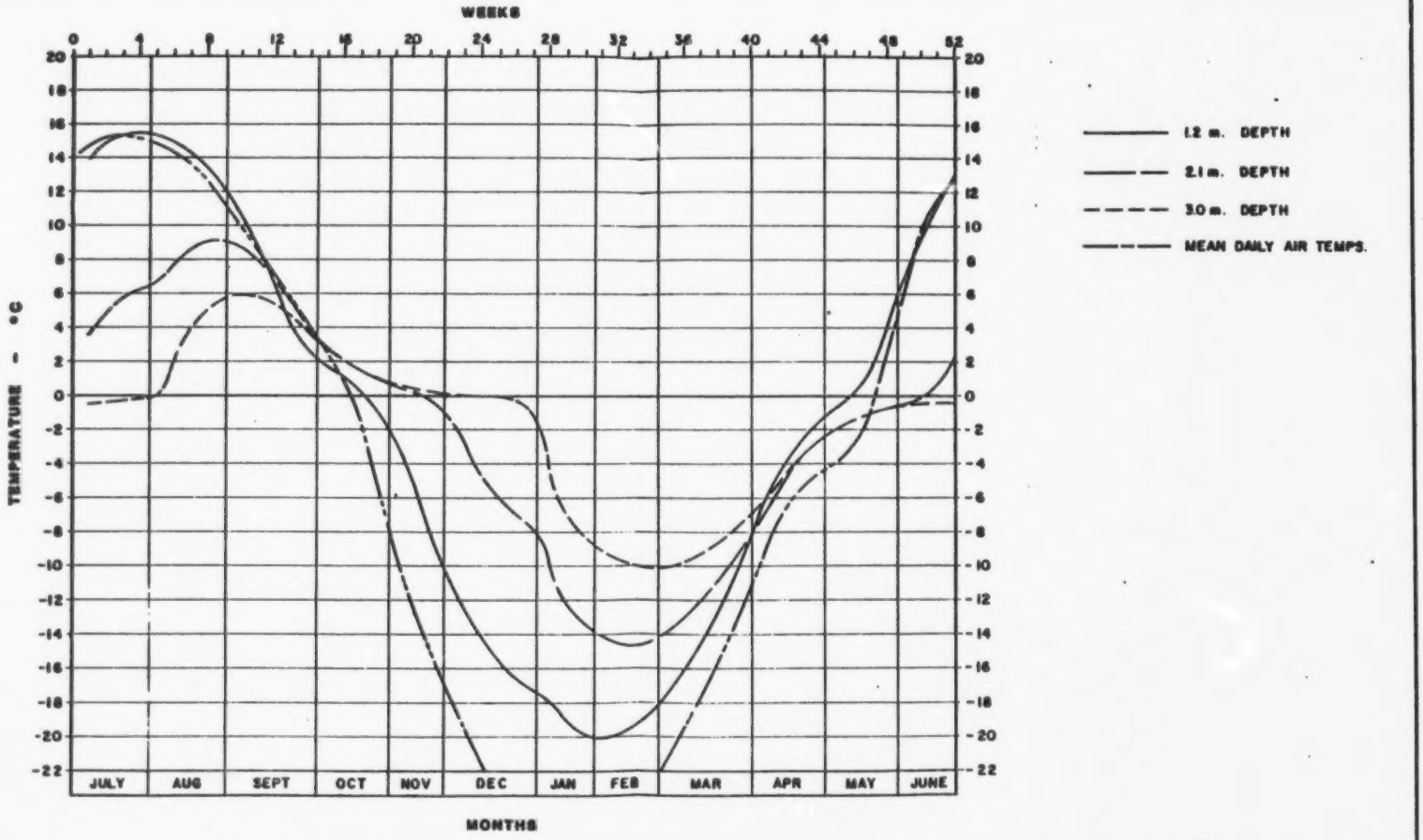
WEEKS
0 4 8 12 16 20 24 28 32 36 40 44 48 52
TEMPERATURE - °C
20 18 16 14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14 -16 -18 -20 -22
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE
MONTHS
1.2 m. DEPTH
2.1 m. DEPTH
3.0 m. DEPTH
MEAN DAILY AIR TEMPS.

SOIL TEMPERATURES BASED ON MEAN DAILY AIR TEMPERATURES

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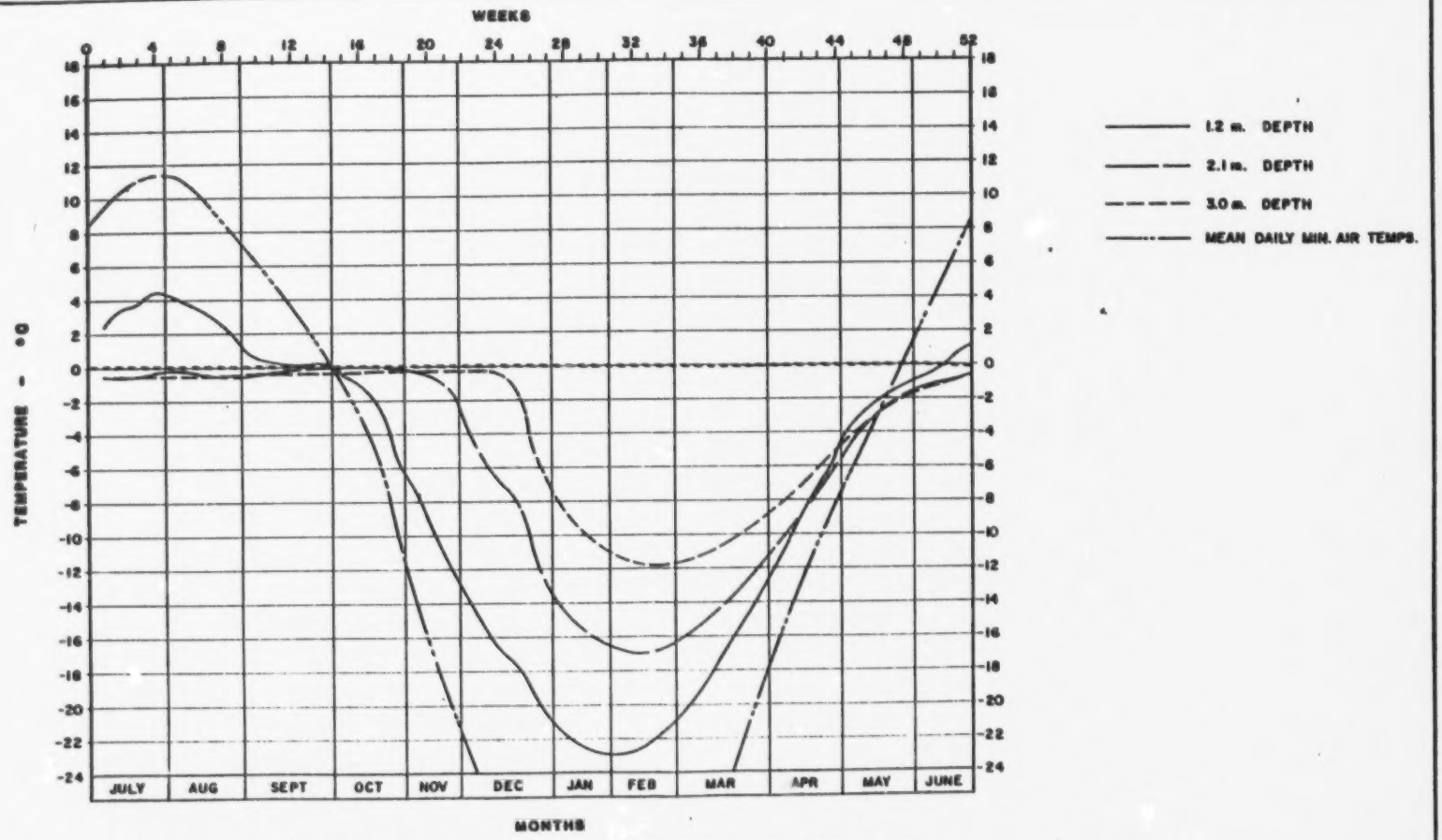
DATE | **FIG. 21**

JOB No. RJ65


WEEKS
0 4 8 12 16 20 24 28 32 36 40 44 48 52
TEMPERATURE - °C
18 16 14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14 -16 -18 -20 -22 -24
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE
MONTHS
1.2 m. DEPTH
2.1 m. DEPTH
3.0 m. DEPTH
MEAN DAILY MIN. AIR TEMPS.

SOIL TEMPERATURES BASED ON MEAN DAILY MINIMUM AIR TEMPERATURES

SPC CO-GENERATION STUDY

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SCALE

FIG. 22

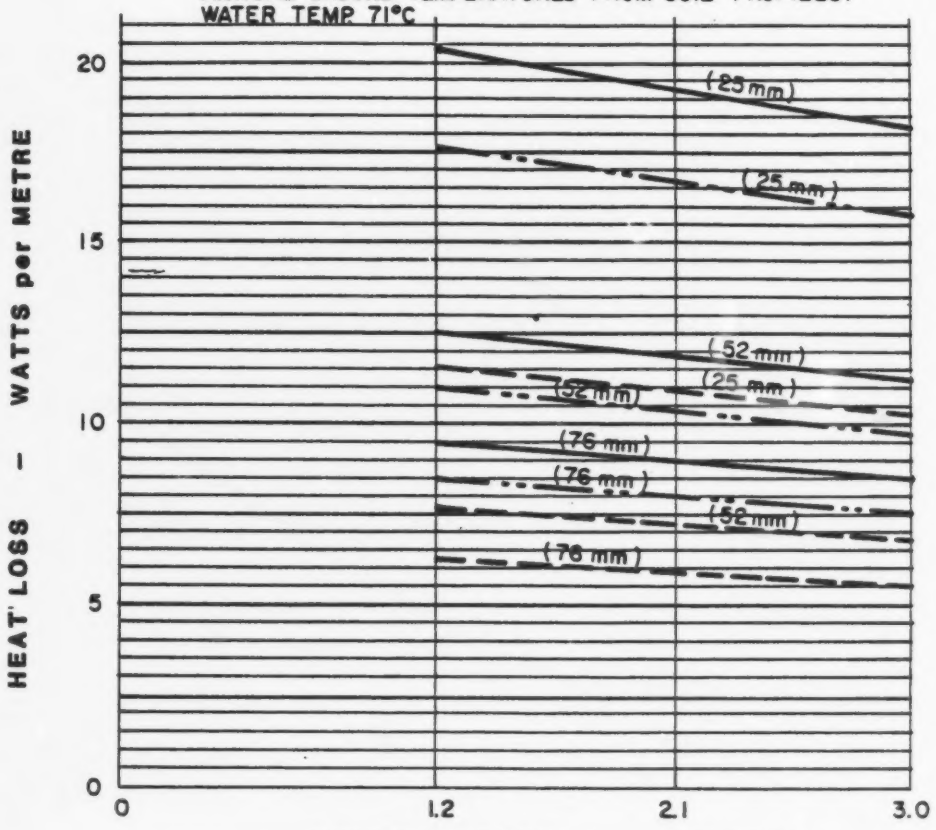
To check the sensitivity of the envelope, a "worst condition" scenario was applied where temperatures were 25% more severe than "normal". At a 1.5 metre depth, the minimum temperature drops by 6°C. This indicates that some variation in heat loss in the piping system will be experienced, depending on air temperature. Other factors such as snow cover, road grading, traffic, vegetation and even colour of the soil will impact the soil temperature.

In addition, the temperature varies with time. Figure 21 shows the expected variations with time for depths of 1.2, 2.1 and 3 metres. Figure 21 is similar to Figure 22 except one whole year of mean minimum temperatures is used to check the sensitivity to temperature variations. As illustrated, it can be seen that the sensitivity lessens with depth. For example, at 1.2 metres the temperature normally reaches -2°C at the end of October, with a minimum of -20°C reached at the end of January. Using the minimum temperatures, the temperature reaches -6°C by the end of October and -23°C at the end of January.

Therefore, the deeper the pipe is buried, the less heat is lost. However, this also results in higher construction cost to bury the pipe. Normally, pipes under travelled surfaces should be buried at a depth of about 1.5 metres. This depth coincides well with the start of the linear portion of the soil temperature envelope. The rate of reduction in heat loss with greater depth of burial is not as great.

It is possible to go into detail on the economic depth of bury for the pipes. Economics were not evaluated in detail here but some trending was examined. Various thicknesses of insulation and various pipe sizes were examined along with depth. In general, changing the depth of bury from 1.5 to 3 metres for pipes insulated with 52 to 26 mm of insulation would only save 1 to 2 watts per metre. The most significant factors affecting heat loss, as shown on Figures 23a, 23b, 24a and 24b, are pipe size and insulation thickness.

NOTE : TEMPERATURE DIFFERENTIALS BASED ON MINIMUM ANNUAL GROUND TEMPERATURES FROM SOIL PROFILES.
WATER TEMP 71°C



25 mm PIPE x 25 mm INSULATION – (25 mm)
25 mm PIPE x 52 mm INSULATION – (52 mm)
25 mm PIPE x 76 mm INSULATION – (76 mm)
50 mm PIPE x 25 mm INSULATION – (25 mm)
50 mm PIPE x 52 mm INSULATION – (52 mm)
50 mm PIPE x 76 mm INSULATION – (76 mm)
65 mm PIPE x 25 mm INSULATION – (25 mm)
65 mm PIPE x 52 mm INSULATION – (52 mm)
65 mm PIPE x 76 mm INSULATION – (76 mm)

HEAT LOSS FOR VARIOUS PIPE SIZES AND DEPTHS

CLIENT/PROJECT
SPC CO-GENERATION STUDY

ASSOCIATED ENGINEERING SERVICES LTD

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APPROVED | SCALE
DATE | DWG No **FIG. 23A**
JOB No.

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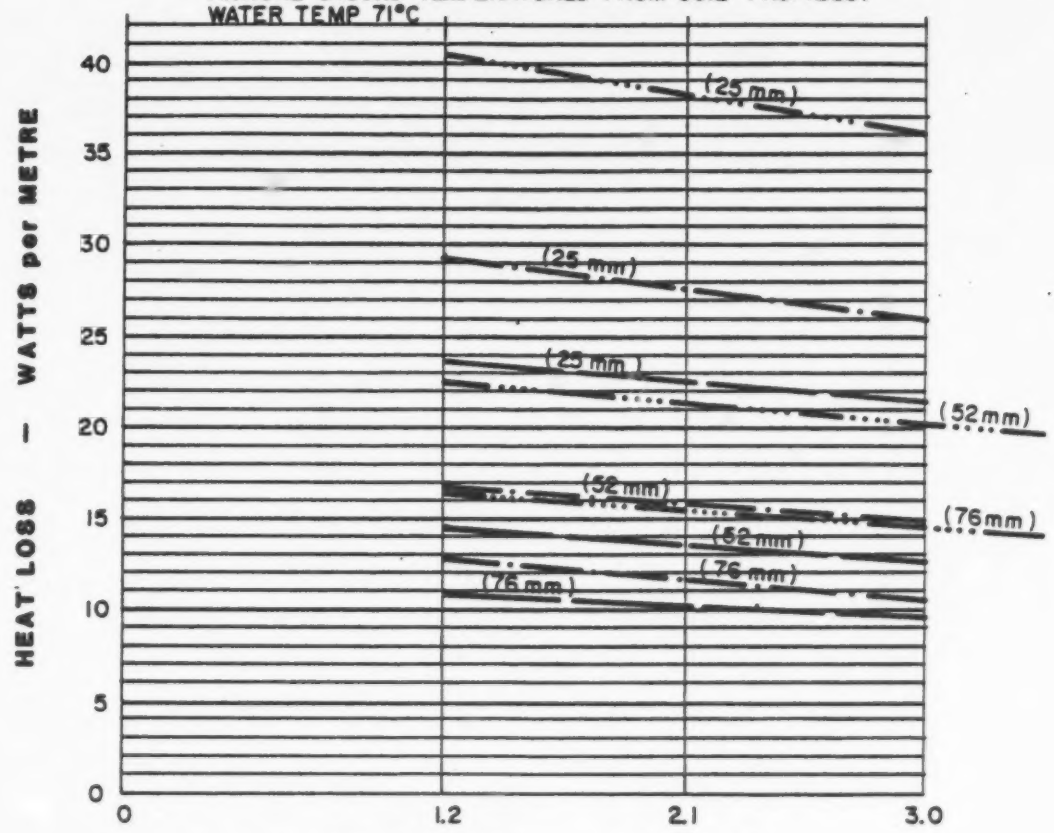
NOTE : TEMPERATURE DIFFERENTIALS BASED ON MINIMUM ANNUAL GROUND TEMPERATURES FROM SOIL PROFILES.
WATER TEMP 71°C



75 mm PIPE x 25 mm INSULATION - (25 mm)

75 mm PIPE x 52 mm INSULATION - (52 mm)

75 mm PIPE x 76 mm INSULATION - (76 mm)

100 mm PIPE x 25 mm INSULATION - (25 mm)

100 mm PIPE x 52 mm INSULATION - (52 mm)

100 mm PIPE x 76 mm INSULATION - (76 mm)

150 mm PIPE x 25 mm INSULATION - (25 mm)

150 mm PIPE x 52 mm INSULATION - (52 mm)

150 mm PIPE x 76 mm INSULATION - (76 mm)

HEAT LOSS FOR VARIOUS PIPE SIZES AND DEPTHS

CLIENT/PROJECT SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE DATE / DWG No. FIG. 23B JOB No.

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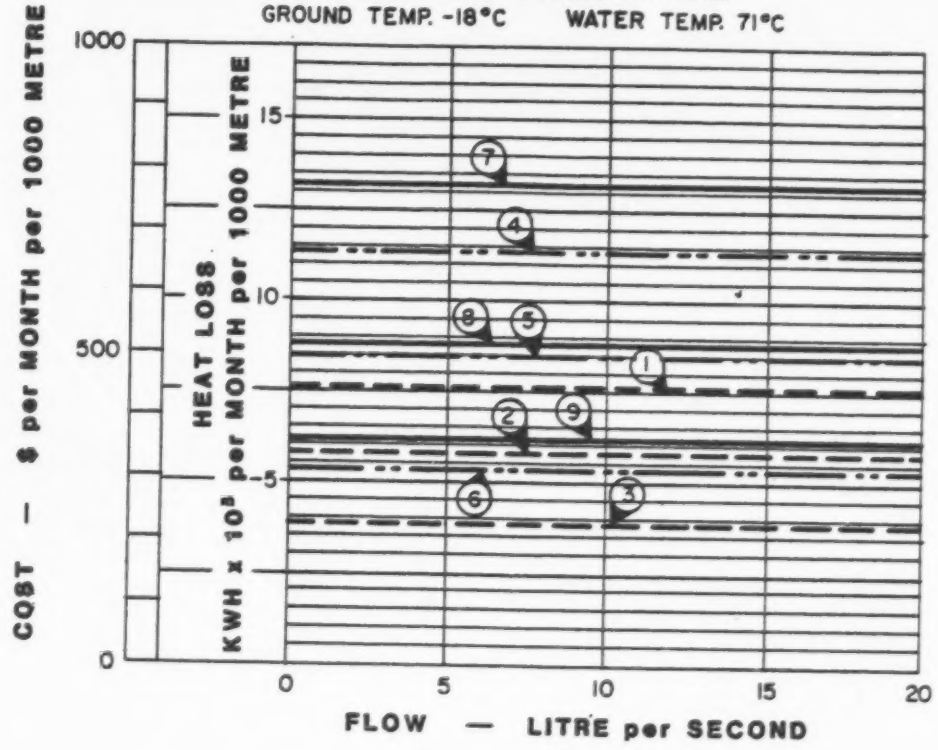
NOTE : INSULATED PIPE COMBINATIONS ARE ASSUMED TO BE BURIED AT 1.5 m.
GROUND TEMP. -18°C WATER TEMP. 71°C



① – 25mm PIPE x 25 mm INSULATION
② – 25mm PIPE x 52 mm INSULATION
③ – 25mm PIPE x 76 mm INSULATION
④ – 50 mm PIPE x 25 mm INSULATION
⑤ – 50 mm PIPE x 52 mm INSULATION
⑥ – 50mm PIPE x 76 mm INSULATION
⑦ – 65 mm PIPE x 25mm INSULATION
⑧ – 65 mm PIPE x 52mm INSULATION
⑨ – 65 mm PIPE x 76mm INSULATION

HEAT CONSUMPTION AND COST FOR VARIOUS INSULATED PIPE AND FLOW RATE

CLIENT/PROJECT
SPC CO·GENERATION STUDY

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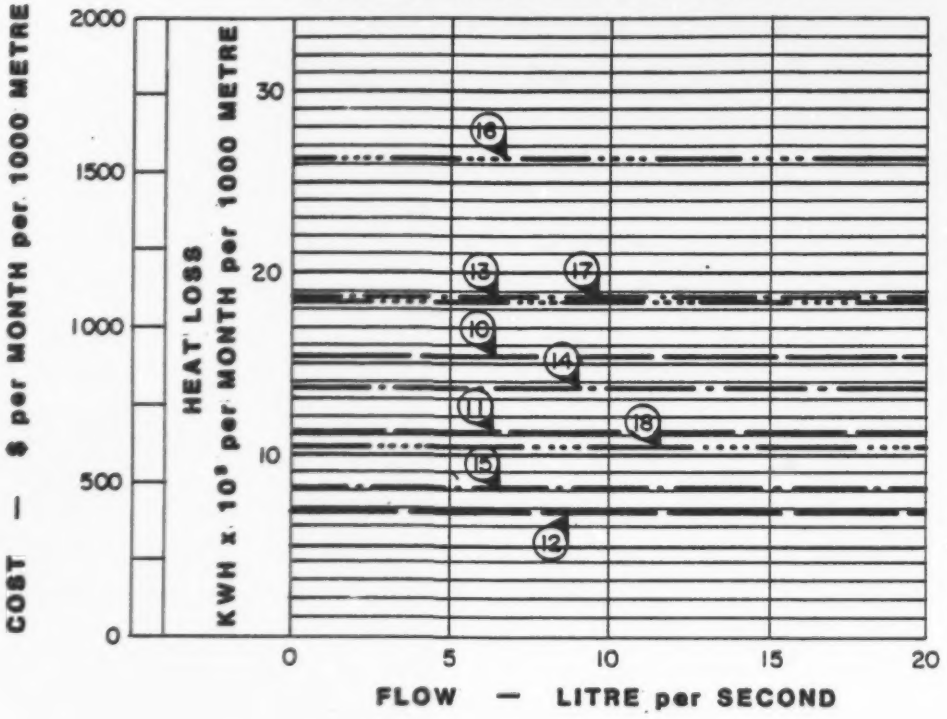
APPROVED	SCALE
DATE	
JOB No.	DWG No **FIG. 24A**

BCIL 5590A · AES

NOTE: INSULATED PIPE COMBINATIONS ARE ASSUMED TO BE BURIED AT 1.5 m. GROUND TEMP. -18°C WATER TEMP. 71°C



⑩ – 75 mm PIPE x 25 mm INSULATION
⑪ – 75 mm PIPE x 52 mm INSULATION
⑫ – 75 mm PIPE x 76 mm INSULATION
⑬ – 100 mm PIPE x 25 mm INSULATION
⑭ – 100 mm PIPE x 52 mm INSULATION
⑮ – 100 mm PIPE x 76 mm INSULATION
⑯ – 150 mm PIPE x 25 mm INSULATION
⑰ – 150 mm PIPE x 52 mm INSULATION
⑱ – 150 mm PIPE x 76 mm INSULATION

HEAT CONSUMPTION AND COST FOR VARIOUS INSULATED PIPE AND FLOW RATE

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD — AES	APPROVED / DATE / JOB No.
	SCALE
	DWG No. FIG. 24B

Figures 24a and 24b show heat loss with various flow rates and pipe sizes. These figures are generally correct for low flows but not exact. Heat loss to the ground is not a function of flow but of temperature difference. For most flow ranges, the variations with flow is negligible.

What is evident from Figure 24a and 24b is the difference pipe size and insulation makes.

The following table illustrates this:

Table 5 - Heat Loss* for Various Pipe and Insulation Thicknesses

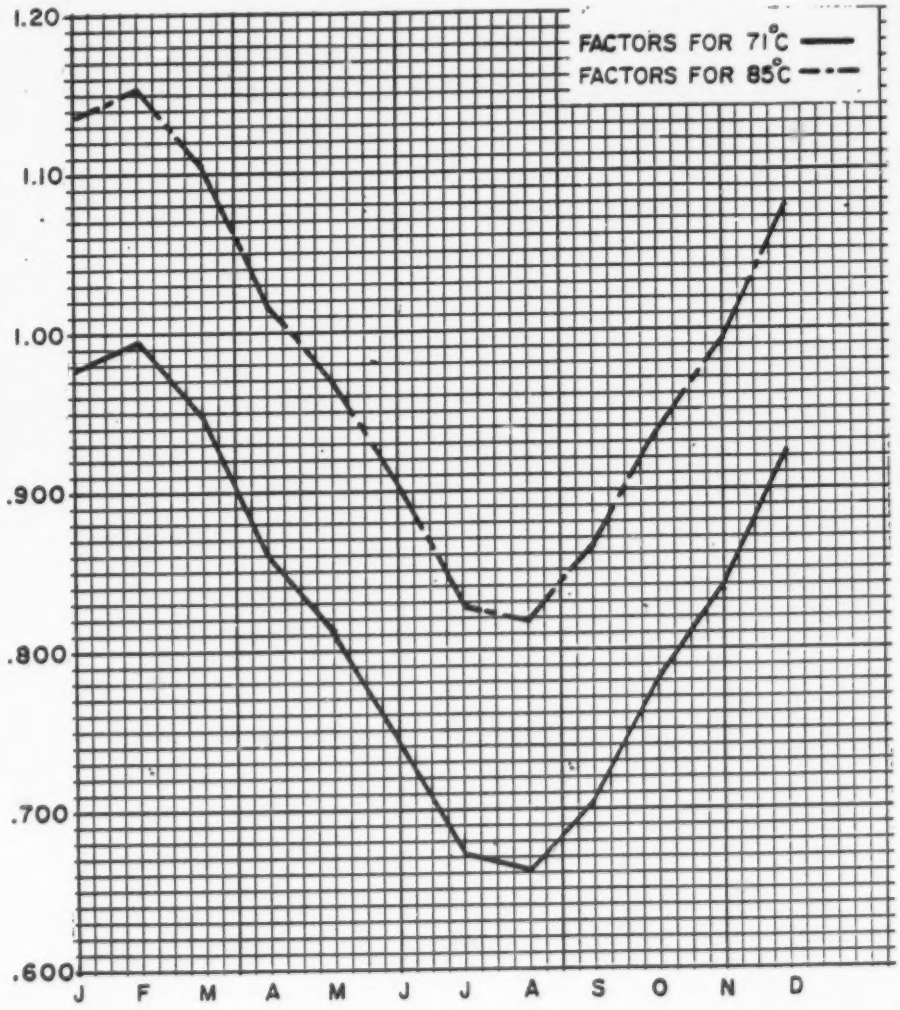
	Insulation Thicknesses		
Pipe Size	25 mm	52 mm	76 mm
100 mm	18.8	13.8	8.2
150 mm	26.3	18.5	10.4

*Heat loss in kW·h x 10^3 per 1000 metres per month.

The graphs were based on a fluid temperature of 71°C and minimum ground temperature at a 1.5 metre depth.

Figure 25 gives monthly heat loss correction factors for the pipes for an alternative, secondary flow temperature of 85°C attainable with a plate heat exchanger and exhaust gas heat recovery.

The final pipe selection should be based on the total economics. In this study, it has been assumed that the pipe will be buried at a depth of 1.5 metres and will have 50 mm of insulation. However, there are some indications that 75 mm of insulation will be cost effective. The value of 8000 kilowatt hours of fuel oil is $ 470.00 per month. The capital value of the extra insulation on 150 mm diameter pipe, amortized at 5, 10 and 15 years, is $ 315.00, $ 207.00 and $ 176.00 per month respectively. However, this comparison is really only valid if the heat loss results in not being able to sell the heat to someone.



PIPE

HEAT LOSS

CORRECTION FACTORS

FOR 1.5M DEPTH

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / DATE / JOB No. — SCALE / DWG No. **FIG. 25**

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The choice will ultimately depend on the pipe size chosen and other factors. A 50 mm insulation thickness has historically been the thickness most often used in other applications with pipe runs of any length. The 30 metre run at Attawapikat used 30 mm of insulation and the 100 metre run at Lac La Martre used 30 mm of insulation.

5.3 HEAT TRANSFER EFFICIENCY OF USERS' EQUIPMENT

The efficiency of transferred heat to the end user is a function of a number of factors.

a) The heat loss from the distribution mains which reduces the supply temperature; and

b) The log mean temperature difference (LMTD) for the heat transfer equipment.

This LMTD is a function of primary and secondary fluid temperatures entering the heat exchange equipment, which are by themselves a function of fluid flow. The higher the LMTD for an exchanger, the better the heat transfer and the smaller the exchanger surface area.

Since most buildings are heated to within the range of 18°C to 22°C in winter, it is important to keep the supply temperature of air in a ventilation system as close to an acceptable temperature range of 40°C to 55°C as this reduces the volume of air required to be circulated which, in turn, reduces duct sizes, fan sizes and cost. In hot water systems, it is necessary to raise the mean temperature of the water as this reduces the area of heating radiation required, thereby, reducing the cost.

There are up to three heat transfer stations before the generator heat reaches the end user. There is a heat exchanger at the generating facility to capture the heat. The heated fluid is then pumped to the

user. The heat may be transferred directly through another fluid to an air exchanger or radiant heat system, or it may be transferred to the user's system in a fluid-to-fluid transfer. In the latter case, the final transfer will be through the users heat exchanger system. Consequently, it is important to achieve the most efficient heat transfer possible. This can be done effectively at the generating station with a plate heat exchanger. At the user end either a plate heat exchanger or shell and tube heat exchanger can be used, depending on the type of secondary system connected to it.

The school is best served by a low temperature radiant floor system. This allows for a higher LMTD value resulting in a smaller heat exchanger since the sub-secondary flow temperature is limited to 53°C. The other advantage relates to the heat storage in the floor. As discussed later in this report, there will be times when the demand exceeds the available heat. This shortfall would flow into the school from the floor structure, thereby, reducing the demand on the oil-fired heating equipment if night setback control is employed. For existing furnaces with limited air flow increase capabilities, the flow through the heat recovery coil may have to be higher than normal in order to maintain a design temperature drop of 10°C. Temperature drops may have to be reduced to 4°C to 6°C in order to improve the LMTD for the coil.

Each system needs to be looked at on its own to optimize air flow and water flow requirements for a given heat transfer. Use of computer programs will greatly simplify the optimum selection. The shortfall of heat availability versus demand will be quickly sensed by an air heating system. The lower the thermal mass of the structure, the quicker the temperatures will change requiring more frequent generation of the oil-fired equipment.

5.4 COINCIDENCE OF DAILY POWER SUPPLY TO HEATING REQUIREMENTS

The various graphs illustrating mean heating requirements and available waste heat have shown that, on average, there is sufficient heat available to heat a number of structures. However, it must be recognized that power is not generated uniformly.

Even though power supply in Wollaston is restricted to lighting and appliances, there are large variations demonstrated on the consumption curve for Wollaston. This curve, as supplied by SPC through North Sask Electric is shown on Figure 6. The minimum load typically occurs between the hours of 6:00 and 7:00 in the morning, rises rapidly between 9:00 and 10:00 (double the minimum), and then reaches a peak around 2:00 in the afternoon.
The demand then appears to drop off rapidly after 7:00 in the evening, reaching a plateau between 10:00 and midnight, and then drops to near minimum by about 3:00 in the morning.

Interestingly, this curve is much flatter on weekends. This is probably related to school loading, commercial loading and weekend activities of the residents.

The important factors about this curve are its implications on heat production and heat demand.

Because it is coldest at night, heat demand, even with thermostat setbacks, is often higher at night. The power consumption is obviously higher during the day than at night. As a consequence, it has to be recognized that when the "mean" amount of available heat is discussed, only a portion of that heat is "available" due to the lack of coincidence between peak heat requirements and peak heat generated.

For example, the current "mean" annual demand is about 98 kW and the mean winter demand is about 110 kW. If the consumer demand in winter were 110 kW on average, the demand could be met or surpassed for about 10 hours between 900 and 1900 hours. For the remainder of the day, supplemental heating may be required.

Because electrical demand increases more rapidly than heat demand, the significance of this deficiency is reduced with time. This situation is also offset by the fact that generator heat output does not vary linearly with electrical demand.

As shown on Figure 5, at a generator output of 350 kW, the waterjacket heat is approximately 350 kW. At a generator output of 100 kW, the waterjacket heat is still nearly 250 kW. Because the engine heat must be maintained, only a portion of this heat is "recoverable". The deficiency in heat during low electrical demand will not be significant in Wollaston due to the proposed relatively low heat demand to be connected to the system.

5.5 COINCIDENCE OF SUPPLY AND DEMAND

There are further factors besides the daily consumption curve characteristics that affect the heat available to consumers.

There are a considerable number of factors that affect the demand on power. We know that power demand in Wollaston increases in the winter over summer by a factor of two. This is probably due to the longer period of darkness in the winter months along with greater home appliance use.

Interestingly, as shown on Figure 11, the heat output does not have the same summertime drop, as the recoverable heat does not drop in proportion to the load at low electrical demands, as proportionally more heat is rejected to the water jacket and flue gas at low load. Fuel

consumption is proportionally higher at low load. Figure 11 does show that for a large portion of the year, there will be significant excess heat available above the mean monthly demand.

However, because space heating is not provided electrically, peak electrical demands will not necessarily coincide with peak heating demands.

Figure 11 has shown various facility demands as additive. For the mean demand, this may be close to true. However, peaking will not necessarily be coincident. For example, heat demand at the school may be relatively high during the night when the school is empty and there is no heat from students or lighting. Heat demand for the water system will be relatively constant for any given month. Heat demand for a laundromat or similar commercial facility may well be highest in the afternoon and evening.

The non coincidence of demand will tend to improve the availability of heat although it is not possible to quantify a factor for this.

5.6 SUMMARY DISCUSSION OF DELIVERABLE WASTE HEAT

The calculations and graphs show that there is adequate available waste heat from the generators to supply a large number of the potential consumers identified. The losses in various components of the system have been examined and demonstrate that delivery of waste heat is technically feasible.

There will be limits on how far it is practical to deliver the heat and the size of the consumer load that is practical to serve. There are also considerations to be made in terms of desirable consumers, ability to finance, cost optimization and design considerations. For example, is 76 mm of insulation as cost effective as 52 mm of insulation? Should heat exchangers be sized to take advantage of the heat in excess

of the mean amount required by the customers? As inferred in the section on coincidence of supply and demand, there will be times when more heat is available than the "mean" amount. Heat exchangers should be sized to take advantage of this heat if it is economically warranted. Details on design considerations are addressed in the appendices. Cost related discussions follow the next section.

6.0 GENERAL SYSTEM DESIGN CONSIDERATIONS

A number of criteria for design of a waste heat recovery system have been addressed in previous sections of this report, or have been alluded to. Part of the scope of this project was to provide as much system design information as possible. While this has been done, detailed design discussion does not assist in making decisions on the project once the study has progressed far enough to assess practicality and costs.

The detailed discussion on selection of equipment, piping and so on has been included as Appendices C and D of this report for those who are interested. The information in the appendices is intended as useful information for anyone considering design of a system or carrying on with implementation of this project.

7.0 COST ESTIMATES

7.1 GENERATING STATION EQUIPMENT

The important components required to transfer the heat from the primary engine cooling circuit to the secondary distribution supply system are the heat exchangers, pumps, controls and liquid expansion vessels. It is important to note that distribution system pipe sizing is dependant on the efficiency of the primary heat exchanger.

1. Water Jacket Heat Exchanger:

Two types of exchangers were examined for efficiency and cost: the shell and tube heat exchanger; and the plate heat exchanger.

Operating flow and temperature conditions were selected for a number of different loads with and without the waste heat recovery from the flue gas, and full engine flow and partial engine flow through the exchanger. The plate heat exchanger was more expensive than the shell and tube heat exchanger but it took up less space and was more efficient. Higher secondary water temperatures were obtainable with the plate heat exchanger for the same return water and primary water temperatures. The LMTD was higher.

There was no change in cost for small changes in output. Cost variations appeared to be more related to flow.

The higher temperature difference across the secondary distribution circuit using a plate heat exchanger has the following impact:

a) Smaller flow rate; (approximately 50% less than with the temperature differences chosen for the comparison)

b) Smaller distribution system pipes could be chosen with reduced heat loss; (100 mm instead of 150 mm)

c) Reduced pipe volumes resulting in a reduced quantity of propylene glycol required; and

d) Reduced fluid volume for 100 mm diameter pipe, resulting in a reduced expansion, resulting in the need for only one expansion tank instead of two.

2. Pumps:

Duplex parallel operating pumps were selected for both the primary subcircuit and the secondary circuit. Because both pumps operate together to produce the design flow, each is smaller than a single pump handling the total duty. Although one pump is less expensive than two smaller pumps, the need for standby still remains and as stated earlier, parallel operating pumps give some flow dependability. Flow may reduce by 25% to 33 1/3% depending on the pump flow characteristics, in the event of a pump failing. Two larger pumps with manual changeover would be more expensive with much less flow reliability.

3. Controls:

The simplest controls were selected. Heat exchanger outputs are controlled by three-port bypass mixing valves with low limit override. This ensures constant flow through the primary subcircuit. Because of the need for control of the return temperature back to the engine, the three-port valve allows for low limit control which is a backup safety measure to the reused primary loop bypass mixing valve, providing double protection in the event of a failure of a valve control circuit or a sudden load occurring on the exchangers. Two-port valves do not provide this safety feature.

4. Expansion Tanks:

As mentioned previously, smaller distribution mains result in a smaller system volume and smaller expansion volume. The size of tank required to accept this volume is smaller.

Two thousand metres of 150 mm diameter pipe operating at 420 kPa requires a tank volume of 2800 litres. Two thousand metres of 100 mm diameter pipe requires a tank volume of approximately 1200 litres offering a considerable saving in cost and space.

5. Exhaust Gas Heat Exchanger:

This unit is expensive. It is recommended that if flue gas heat recovery is used, only one be used per pair of engines with gas side and glycol side valving to permit either engine or no engines to use the exchanger. In the future when both engines have to be run, an additional exchanger would be installed together with ancillary control equipment.

6. Cost Summary:

a) Jacket Recovery Only:

- Plate heat exchanger	$ 7,000
- Pumps	5,000
- Three bypass control valves with sensors	9,000
- Pipe fittings, insulation and instrumentation	21,000
Total:	$ 42,000

b) Additional Cost for Exhaust Gas Recovery:

- Exhaust heat exchanger with insulation and bypass control	$ 43,000
- Exhaust system bypass	8,000
- Lifting equipment for exchanger	3,000
- Control valve	3,000
- Piping, insulation and instrumentation	8,000
Total:	$ 65,000

7.2 PIPING SYSTEMS

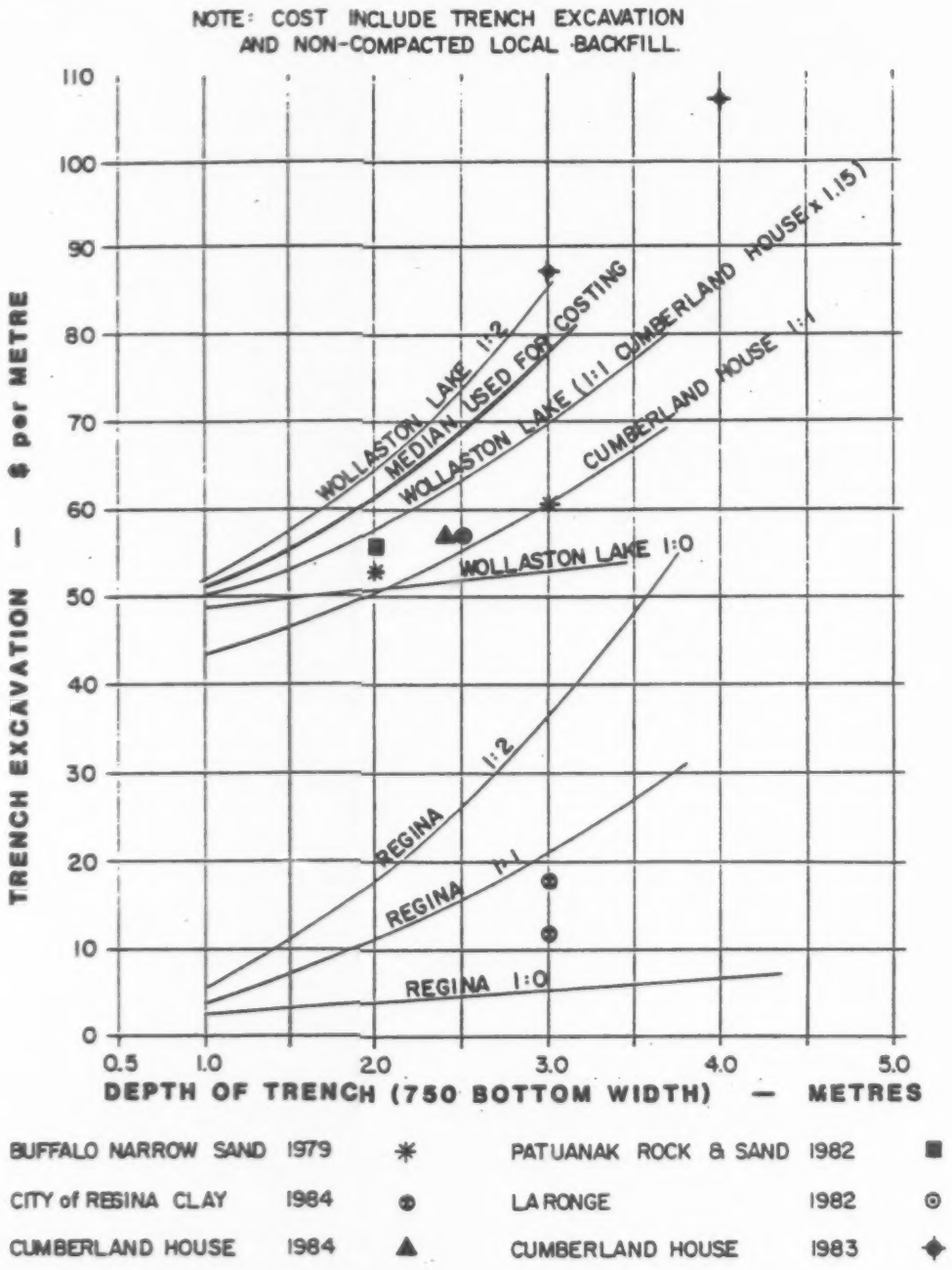
The cost of a piping system to deliver heat to the consumers is made up of several items - pipe costs, insulation, excavation and backfill, pumping of the fluid heat transfer medium, and cost of heat losses to the ground.

In the analysis of the costs of various components, graphs were developed in order to assess the optimum system.

Frequently, the figures were made up in such a fashion as to allow data from several figures to be combined into a final graph; or to be combined to infer certain results; or to allow sensitivity comparisons or comparison between alternatives.

Figure 26, for example, shows trench excavation costs versus depth for a number of locations and soil conditions. A number of actual recent tender prices were plotted to show the variations in costs. The costs for trenching takes into account site accessibility and ground conditions.

This graph demonstrates that it is probably not economic to bury the pipe deeper than 1.5 metres. The saving in fuel costs between 1.5 and 3 metres bury would only be about $ 45 per month per 1000 metres of pipe while the extra capital cost of the extra bury would be in the order of $ 260 per month per 1000 metres (amortized for 25 yrs at 13%).



TRENCH EXCAVATION COST FOR VARIOUS DEPTHS AND COMMUNITIES

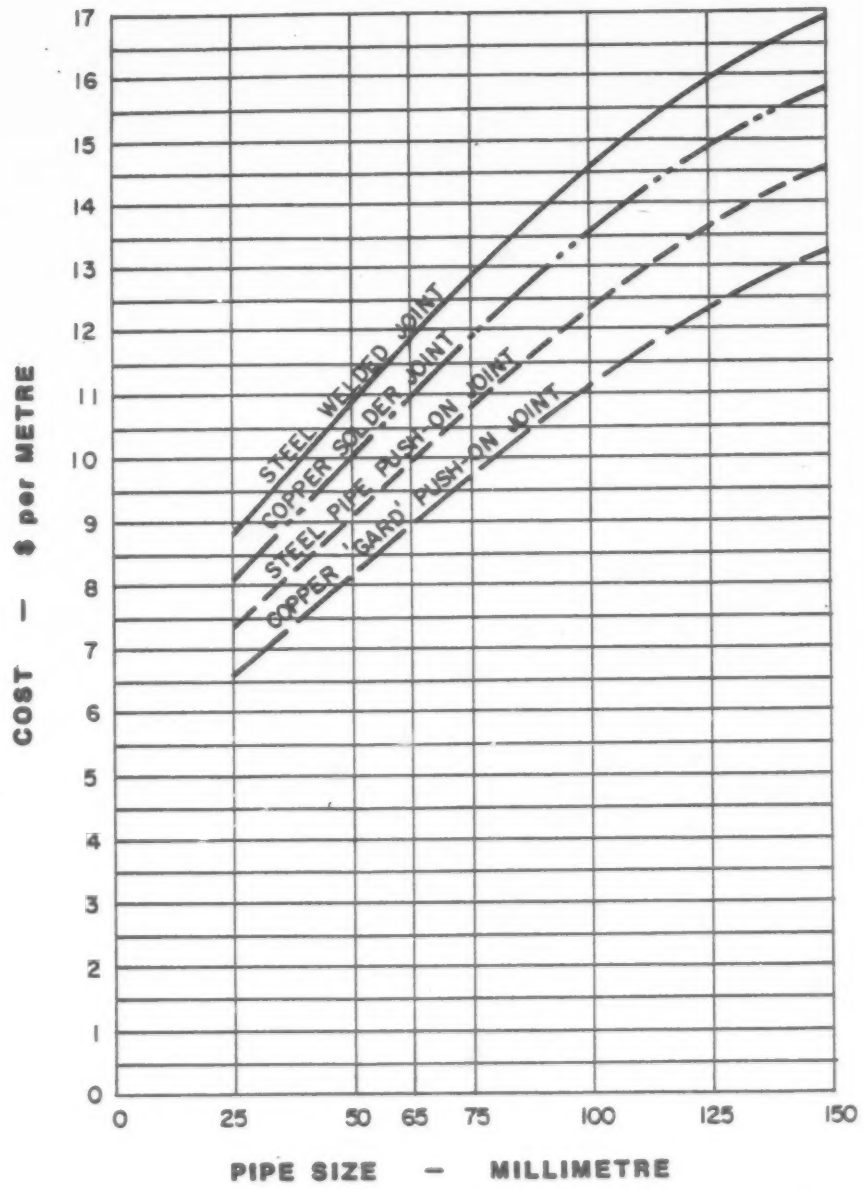
CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / DATE / JOB No. / SCALE / DWG No. FIG. 26

BCIL 5390A-AES

Figure 27 demonstrates the installation costs for various sizes of pipes and types of joints. Figures 28a and 28b show the pipe costs for various suppliers' systems for different pipes and insulation thicknesses. These graphs show that welded steel, insulated pipe, as supplied by Shaw Pipe, is the least costly material. What the graphs do not show, is the high cost of expansion compensators for the welded pipe system. Expansion loops or compensators will add $ 10 to $ 20 per metre to the piping cost depending on pipe size (100 mm to 150 mm diameter assumed) and spacing of expansion loops or compensators. This cost is not sufficient to change the pipe joint selection. Expansion compensation and spacing will have to be addressed in any system design that takes place. Expansion compensation is discussed further in Appendix C.

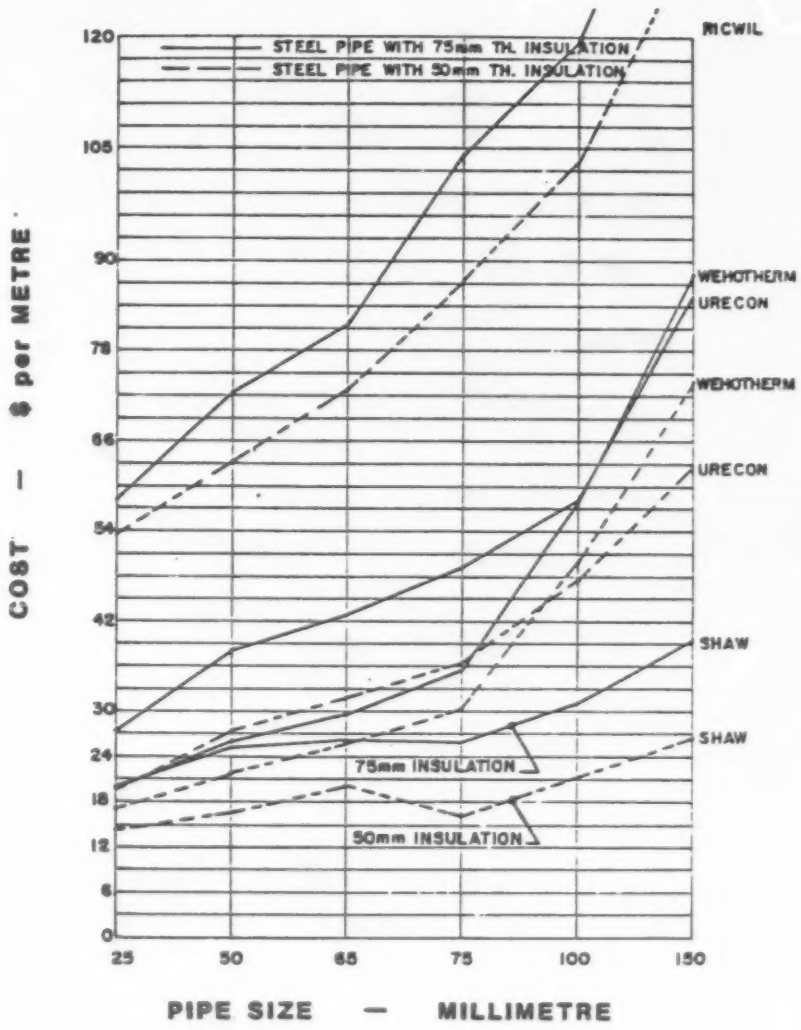
In addition to heat loss and capital cost of the pipe and insulation, the next critical selection factor is the flow rate of the transfer fluid. This, in turn, has to be related to the heat exchangers being used. A high cost efficient heat exchanger can pay for itself in reduced pumping costs and in pipe size reductions when compared to a lower cost, lower efficiency heat exchanger. The rapidly escalating cost of pumping, with increased flow, is demonstrated on Figure 29.

Figures 30a, 30b and 30c show the monthly winter costs for various size pipes and flows. These figures also demonstrate the effect that different paybacks on captial investments and different interest rates have. The pipes for this project will be 100 mm or 150 mm diameter, depending on the number of structures to be serviced and heat exchanger type. The crossover point for selecting 150 mm diameter pipe over 100 mm diameter pipe is at slightly over 9 litres per second for all three payback periods. Although a longer payback period and lower interest rates move the crossover point to the left, the movement is not significant. With plate heat exchangers at 85°C, the required flow of 8.6 litres per second is very close to the crossover point.



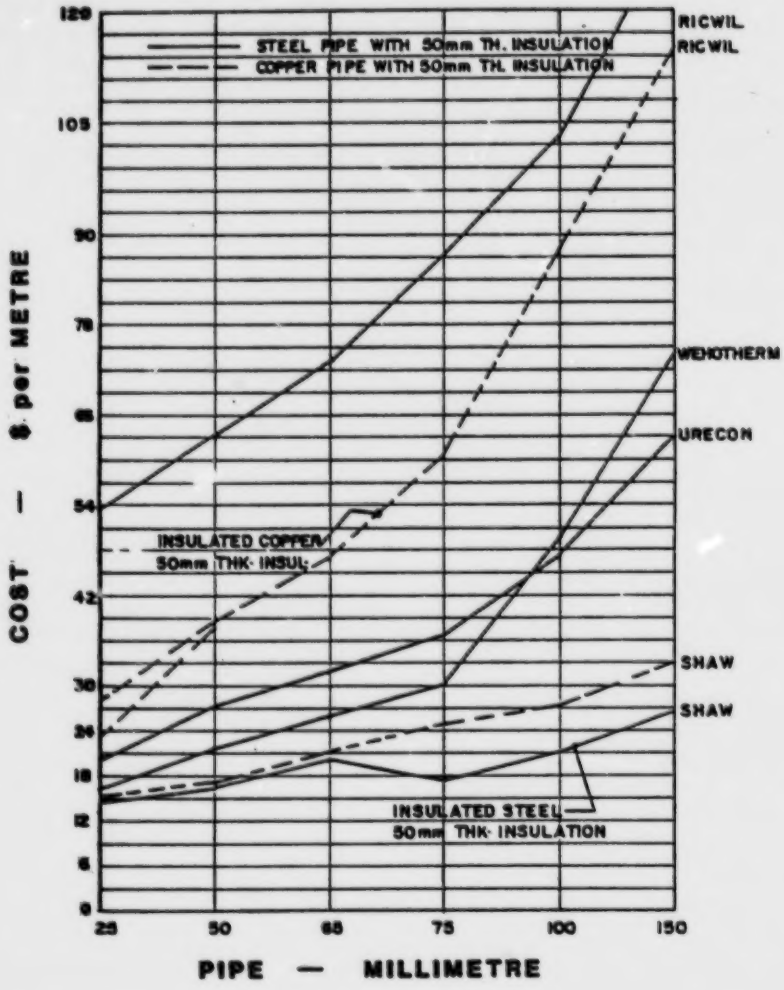
PIPE INSTALLATION COST ESTIMATE FOR VARIOUS SIZES AND JOINT TYPES

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
AES	DATE / DWG No. **FIG.27**
BCIL 3590A-AES	JOB No.



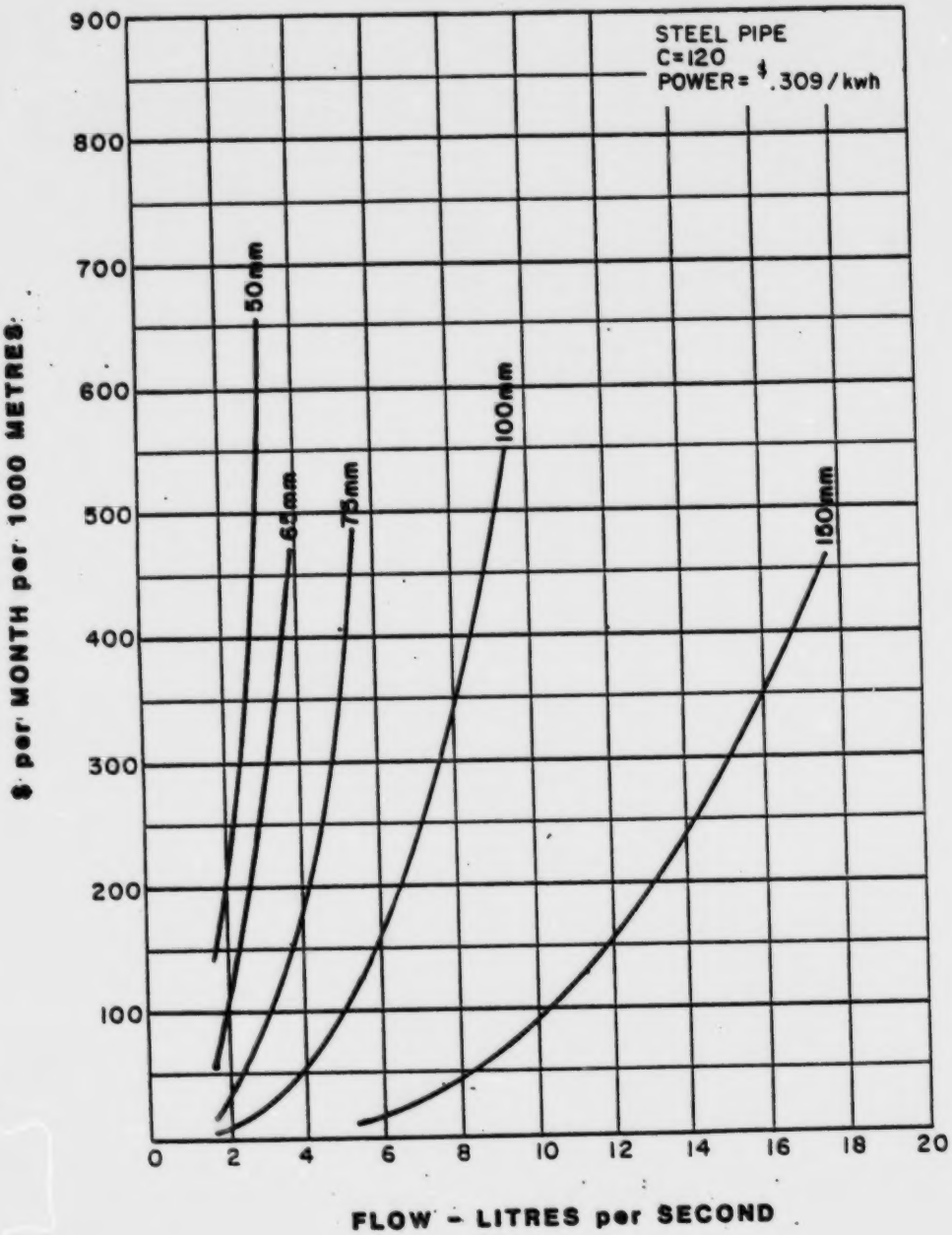
PIPE MATERIAL COST FOR VARIOUS SYSTEMS

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / SCALE
	DATE / DWG No. **FIG. 28A**
	JOB No.



PIPE MATERIAL COST FOR VARIOUS SYSTEMS

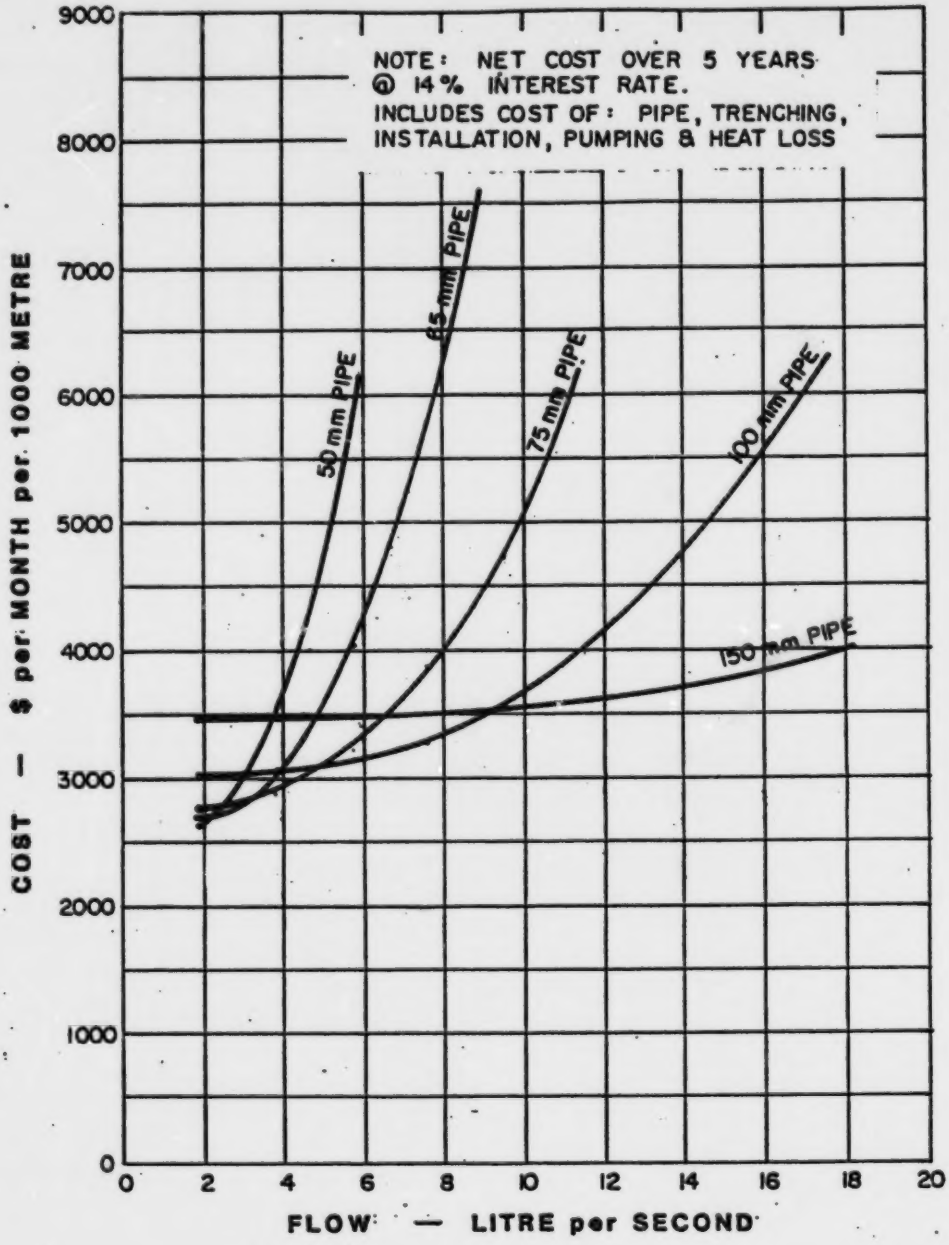
CLIENT/PROJECT **SPC CO·GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / SCALE
	DATE / DWG No. **FIG. 28B**
	JOB No.



PUMPING COSTS FOR VARIOUS PIPE SIZES

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE DATE / DWG No. **FIG. 29** JOB No.

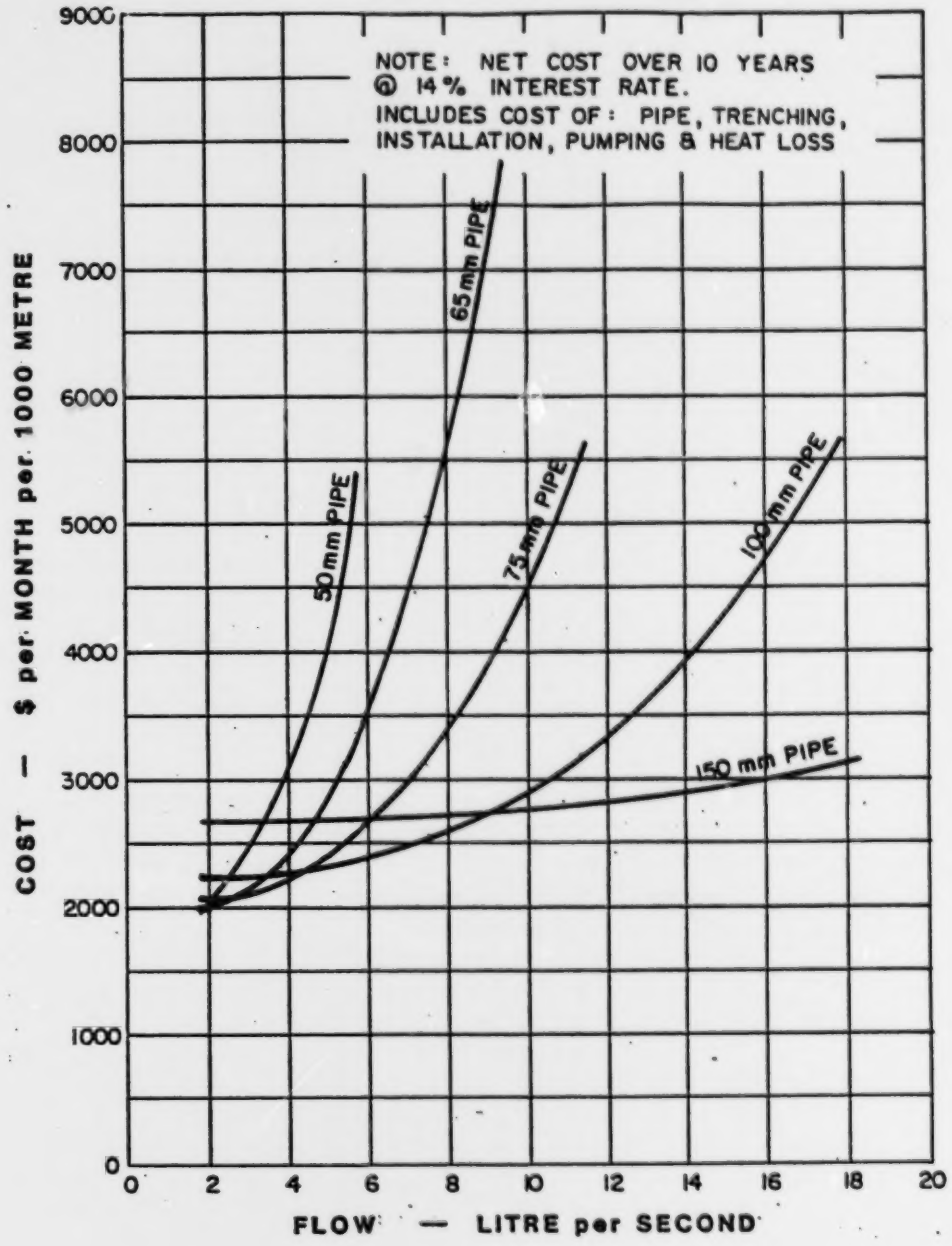
BCIL 5590A - AES



PIPE SYSTEM NET COST
FOR VARIOUS FLOW RATES

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / DATE / JOB No.
AES	SCALE / DWG No. FIG. 30A

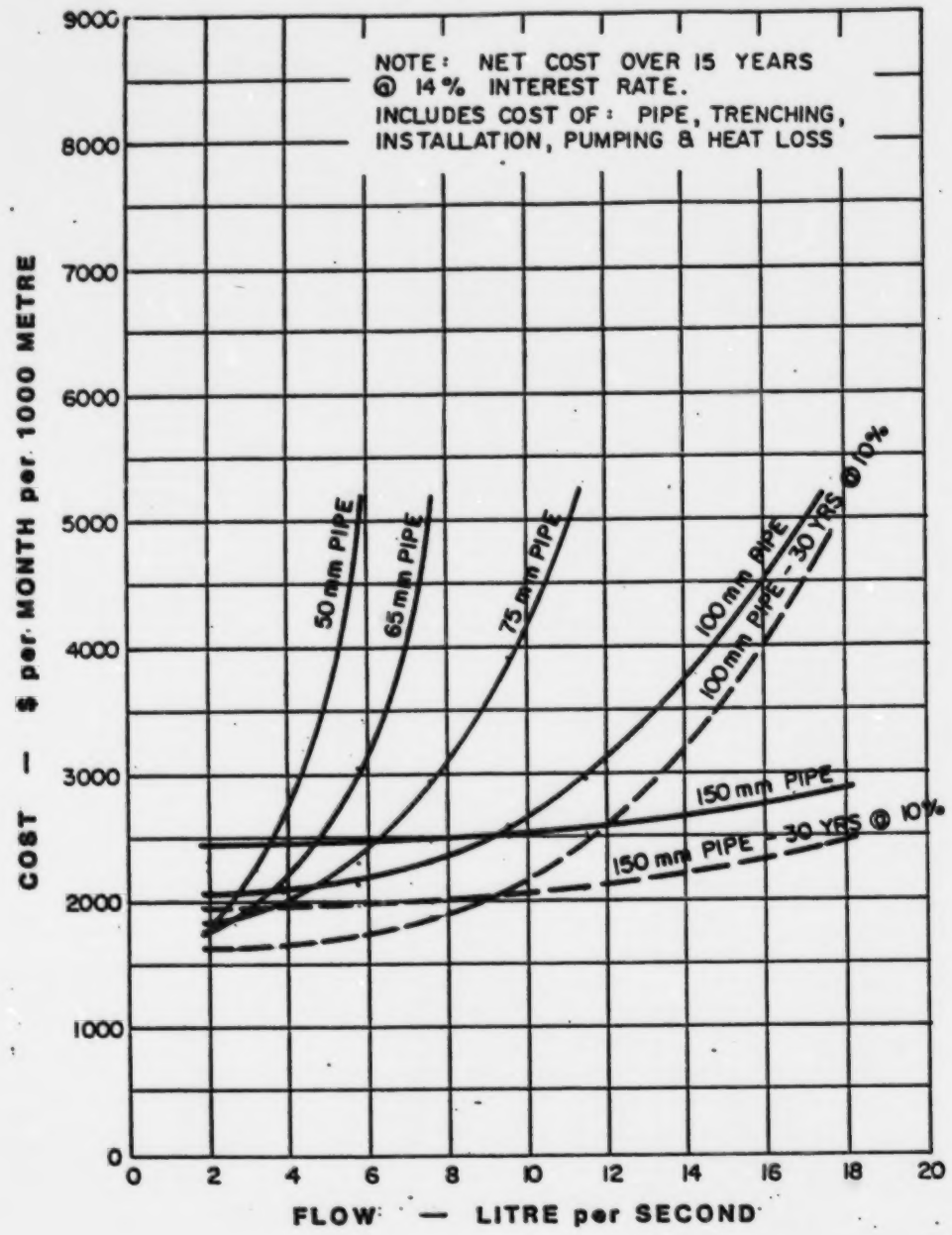
BCIL 3590A - AES



PIPE SYSTEM NET COST
FOR VARIOUS FLOW RATES

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / SCALE
	DATE / DWG No. **FIG. 30B**
	JOB No.

BCIL 3590A - AES



PIPE SYSTEM NET COST FOR VARIOUS FLOW RATES

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD — AES	APPROVED / DATE / JOB No. — SCALE / DWG No. FIG. 30C

DCIL 3398A - AES

7.3 USER EQUIPMENT

The selection of heat exchangers, pumps and controls was made on the same basis as described for the generating station equipment.

1. Cost Summary:

a) New School:

- Heat exchanger	$ 3,000
- Heat metering equipment	3,500
- Control valves and sensors	3,500
- Pumps	4,000
- Pipe, fittings and insulation	21,000
- Trenching	2,000
Total:	$ 37,000

b) Laundromat:

- Heat exchanger	$ 2,000
- Heat meter	2,000
- Pumps	2,500
- Pipe, fittings and insulation	10,500
- Trenching	1,500
- Unit heaters	2,500
Total:	$ 21,000

c) Water System:

- Heat exchanger	$ 1,500
- Heat meter	1,500
- Pumps	2,500
- Pipe, fittings and insulation	6,000
- Trenching	1,000
- Unit heaters	1,500
- Building	15,000
Total:	$ 29,000

d) Health Clinic:

- Heat meter	$ 2,000
- Heating coil, mixing valves and sensors	6,500
- Pumps	2,000
- Pipe, fittings, modifications to existing equipment	5,500
- Trenching	2,000
Total:	$ 18,000

e) Residential:

- Heat meter	$ 1,500
- Heating coils, mixing valves and sensors	1,500
- Pipe, fittings, modifications to existing equipment	4,000
- Trenching	2,000
Total:	$ 9,000

7.4 OPERATING AND MAINTENANCE

Operating costs for the system, in terms of pumping, have been evaluated on the basis of the cost of pumping the fluid transfer medium. Maintenance and maintenance operations for the heat recovery equipment, delivery piping, and consumer heat exchangers has been assessed at 2% of the total capital cost per year. Although this is, at times, a large amount, it can be shown to be low in some cases. SPC's experience with operation and maintenance of other similar utilities may require adjustment of this allowance.

The heat recovery system, in practice, should require very little maintenance. However, a single service connection failure, for example, could cost several thousand dollars to repair. Due to the isolated nature of Wollaston Lake. A major problem once every 5 years could use funds set aside.

7.5 SIMPLE ANNUAL COST CALCULATIONS

In order to determine the viability of different levels of service, a number of different concepts were examined and annual costs prepared. The tables on the following pages tabulates the results. In preparing these costs, the service levels were priorized and combined as follows:

Priorized Services:	Combinations for Analysis:
1. Generator Building	1 through 6 - Full system
2. School	1 + 6
3. Water System	1 + 5
4. Laundromat	1 + 4
5. Health Clinic	1 + 3
6. Five Houses	1 + 2
	1 + 2 + 3
	1 + 2 + 3 + 4
	1 + 2 + 5
	1 + 2 + 5 + 6

7.6 INITIAL ECONOMIC SERVICEABILITY OF CUSTOMERS/ECONOMIC SERVICE DISTANCE

The above simple annual cost calculations show that the system is not economic for any of the situations analyzed for delivery distances of 1000 metres. However, there are some additional variables that need to be considered. The tables following are based on a fixed service distance to the customer of 1000 metres. Since pipe costs, pumping costs, maintenance costs and heat loss are all proportional to distance, it is possible to fix the distance at which it may be economic to serve the buildings in question. By assembling the data presented in the tables and plotting annual cost versus distance from source, a rough estimate of service limitations can be made. In addition, an evaluation of the potential selling price of the heat can be made.

COST ANALYSIS FOR:	1000 M																					
Buildings Served	2 to 6		6		5		4		3		2		2 + 3		2 + 3 + 4		2 + 5		2 + 3 + 6	
Required Flow (L/s)*	17.63	8.6	1.0	0.5	1.63	0.8	3.2	1.6	0.8	0.4	11.0	5.3	11.8	5.7	12.8	7.3	12.62	6.1	12.62	6.6
Supply Main Pipe Size (mm)**	150	100	50	50	50	50	50	50	50	50	150	100	150	100	150	100	150	100	150	100
A. Capital cost of generator building heat equipment and piping***	79,281	68,974	9,750	9,750	9,750	9,750	9,750	9,750	9,750	9,750	56,390	49,060	59,215	51,515	71,800	61,750	62,050	54,000	69,490	56,950
B. Capital cost of building services (not including generator building heat)+	144,505		43,985		10,006		21,000		28,672		36,952		65,624		86,624		94,958		98,943	
C. Capital cost of 1000 m system (installed)	162,660	134,957	111,804		111,804		111,804		111,804		162,660	134,957	162,660	134,957	162,660	134,957	162,660	134,957	162,660	134,957
D. Total capital cost (Items A, B and C)	386,246	348,436	165,539		130,560		142,554		150,226		259,802	220,969	286,939	252,096	320,084	283,331	279,668	243,919	326,093	290,050
E. Annual capital cost for 15 years at 13%	99,768	55,918	25,616		21,596		22,060		25,246		30,583	34,193	44,401	39,010	49,530	43,843	43,245	37,744	50,578	45,007
F. Pumping cost for 1000 m system for 6 winter months (Fig 30)++	5,600	4,920	960	360	1,440	900	3,240	1,400	900	300	1,440	1,260	1,800	1,680	3,600	3,000	2,160	1,920	2,520	2,400
G. Heat loss cost for 1000 m system for 6 winter months using winter ground temperatures 71°C	11,816	8,752	5,474		5,474		5,748	5,474	5,474		11,816	8,752	11,816	8,752	11,816	8,752	11,816	8,752	11,816	8,752
85°C	13,806	10,228	6,396		6,396		6,716	6,396	6,396		13,806	10,228	13,806	10,228	13,806	10,228	13,806	10,228	13,806	10,228
H. Maintenance cost assumed as 2% of Item D	7,725	6,969	3,311		2,791		2,851		3,005		5,116	4,419	5,739	5,042	6,402	5,667	5,589	4,878	6,537	5,801
I. Total annual cost (Items E, F, G and H) 71°C	84,090	74,559	35,361	30,761	31,301	30,761	33,099	31,785	32,625	32,025	57,955	48,629	63,756	54,484	71,348	61,262	62,810	53,394	71,491	61,976
85°C	86,899	76,035	36,283	30,683	32,223	31,683	34,067	32,707	33,547	32,947	59,945	50,100	69,746	59,960	73,338	62,738	69,800	54,770	73,441	63,452
J. Six winter months Heat Demand (kw-h)	851,000		57,000		89,000		99,000		79,100		531,000		610,100		709,100		616,000		673,000	
Value of Item J in fuel oil 15.6¢/(kw-h) (40¢/L)	48,081.50		3,220.50		4,802.50		5,503.50		4,469.15		30,001.50		34,470.69		40,064.15		34,804.00		38,024.50	

NOTE: 1ST COLUMN IS SHELL AND TUBE HEAT EXCHANGER; 2ND COLUMN IS PLATE HEAT EXCHANGER.

* Required flow is based on heat exchanger requirements.

** Pipe size is determined from Figure 31c.

*** Capital cost of all systems is based on a single water jacket heat recovery system. Flue gas recovery is approximately $ 65,000 per unit and is not economical.

+ Capital cost of building services is the cost of the user's equipment plus his service connection.

++ Initially, the winter 6 month demand has been examined although the system may well operate throughout the year.

COST ANALYSIS FOR:	100 M						150 M						200 M				250 M			
Buildings Served	2 to 6		4		2		2 to 6		4		2		2 to 6		2		2 to 6		2	
Required Flow (L/s)*	17.63	8.6	3.2	1.6	11.0	5.3	17.63	8.6	3.2	1.6	11.0	5.3	17.63	8.6	11.0	5.3	17.63	8.6	11.0	5.3
Supply Main Pipe Size (mm)**	150	100	50	50	150	100	150	100	50	50	150	100	150	100	150	100	150	100	150	100
A. Capital cost of generator building heat equipment and piping***	79,281	68,974	9,750	9,750	56,390	49,060	79,281	68,974	9,750		56,390	49,060	79,281	68,974	56,390	49,060	79,281	68,974	56,390	49,060
B. Capital cost of building services (not including generator building heat)+	144,505		21,000		36,952		144,505		21,000		36,952		144,505		36,952		144,505		36,952	
C. Capital cost of specified length of system (installed)	16,246	13,495	11,100		16,426	13,496	24,369	20,243	16,770		24,369	20,243	32,492	26,990	32,492	26,990	40,615	33,738	48,619	33,738
D. Total capital cost (Items A, B and C)	240,032	226,979	41,850		109,568	99,508	248,155	233,772			117,711	106,253	256,278	240,469	125,834	113,002	264,401	247,267	133,957	119,750
E. Annual capital cost for 15 years at 13%	37,143	35,122	6,488		16,958	15,398	38,400	36,167			18,215	16,442	39,657	37,211	19,472	17,486	40,914	38,263	20,729	18,530
F. Pumping cost for specified length of system for 6 winter months (Fig 30)++	560	492	324	140	144	126	840	738			216	189	1,120	984	288	252	1,400	1,230	360	315
G. Heat loss cost for specified length of system for 6 winter months using winter ground temps.++ 71°C	1,182	875	575	547	1,182	875	1,773	1,313			1,773	1,313	2,364	1,750	2,364	1,750	2,955	2,188	2,955	2,188
85°C	1,381	1,023	672	640	1,381	1,025	2,072	1,535			2,072	1,535	2,762	2,046	2,762	2,046	3,453	2,558	3,453	2,558
H. Maintenance cost assumed as 2% of Item D	4,801	4,539	839		2,192	1,990	4,963	4,674			2,354	2,125	5,126	4,809	2,517	2,260	5,288	4,945	2,679	2,395
I. Total annual cost (Items E, F, G and H) 71°C	43,182	41,028	8,226	8,014	20,476	18,389	45,976	42,892			22,558	20,069	48,267	44,754	24,641	21,748	50,557	46,626	28,723	23,428
85°C	43,381	41,176	8,323	8,107	20,675	18,537	46,279	43,114			22,857	20,291	48,665	45,050	25,009	22,044	51,055	46,986	27,224	23,798
Value of Item J in fuel oil (9.65¢/kW*h) (40¢/L)	48,081		5,593		30,001.50		48,081				30,001.50		48,081		30,001		48,081		30,001	

NOTE: 1ST COLUMN IS SHELL AND TUBE HEAT EXCHANGER; 2ND COLUMN IS PLATE HEAT EXCHANGER.

* Required flow is based on heat exchanger requirements.

** Pipe size is determined from Figure 31c.

*** Capital cost of all systems is based on a single water jacket heat recovery system. Flue gas recovery is approximately $ 65,000 per unit and is not economical.

+ Capital cost of building services is the cost of the user's equipment plus his service connection.

++ Initially, the winter 6 month demand has been examined although the system may well operate throughout the year.

COST ANALYSIS FOR:	300 M				400 M				500 M				600 M				700 M	
Buildings Served	2 to 6		1		2 to 6		1		2 to 6		1		2 to 6		1		1	
Required Flow (L/s)*	17.63	9.6	11.0	5.3	17.63	9.6	11.0	5.3	17.63	9.6	11.0	5.3	17.63	9.6	11.0	5.3	11.0	5.3
Supply Main Pipe Size (mm)**	150	100	150	100	150	100	150	100	150	100	150	100	150	100	150	100	150	100
A. Capital cost of generator building heat equipment and piping***	79,281	68,974	56,380	49,060	79,281	68,974	56,380	49,060	79,281	68,974	56,380	49,060	79,281	68,974	56,380	49,060	56,380	49,060
B. Capital cost of building services (not including generator building heat)+	144,505		36,952		144,505		36,952		144,505		36,952		144,505		36,952		36,952	
C. Capital cost of specified length of system (installed)	48,738	40,485	48,738	40,485	64,984	53,980	64,984	53,980	81,230	67,475	81,230	67,475	97,476	80,970	94,436	80,970	113,722	94,463
D. Total capital cost (Items A, B and C)	272,524	253,964	142,080	126,497	288,770	267,459	158,326	139,982	305,016	280,954	174,572	155,487	321,262	294,449	190,818	166,982	207,864	188,477
E. Annual capital cost for 15 years at 13%	42,171	39,299	21,988	19,574	49,685	41,387	24,500	21,663	47,199	43,475	27,014	23,751	49,713	45,564	29,528	25,839	32,041	27,927
F. Pumping cost for specified length of system for 6 winter months (Fig 36)++	1,680	1,476	432	378	2,240	1,968	576	504	2,800	2,460	720	630	3,360	2,952	864	756	3,920	3,444
G. Heat loss cost for specified length of system for 6 winter months using winter ground temps.++	71°C	3,546	2,625	3,546	2,625	4,728	3,500	4,728	3,500	5,910	4,375	5,910	4,375	7,092	5,250	7,092	5,250	8,274	6,125
	85°C	4,143	3,069	4,143	3,069	5,524	4,092	5,524	4,092	6,905	5,115	6,905	5,115	8,286	6,138	8,286	6,138	9,667	7,161
H. Maintenance cost assumed as 2% of Item D	5,450	5,079	2,842	2,530	5,775	5,349	3,166	2,800	6,100	5,619	3,491	3,070	6,426	5,889	3,861	3,340	4,141	3,610
I. Total annual cost (Items E, F, G and H)	71°C	52,847	48,479	28,808	29,107	57,428	52,204	32,970	28,467	62,009	55,929	37,135	31,826	66,591	59,655	41,300	39,189	48,376	41,106
	85°C	53,444	48,923	29,403	29,951	58,224	52,796	33,766	29,059	63,004	56,669	38,130	32,556	67,789	60,543	42,494	36,073	49,769	42,142
Value of Item J in fuel oil (5.65¢/MJ'h) (40¢/L)	48,081		30,001		48,081		30,001		48,081		30,001		48,081		30,001		30,001	

NOTE: 1ST COLUMN IS SHELL AND TUBE HEAT EXCHANGER; 2ND COLUMN IS PLATE HEAT EXCHANGER.

* Required flow is based on heat exchanger requirements.

** Pipe size is determined from Figure 31c.

*** Capital cost of all systems is based on a single water jacket heat recovery system. Flue gas recovery is approximately $ 65,000 per unit and is not economical.

+ Capital cost of building services is the cost of the user's equipment plus his service connection.

++ Initially, the winter 6 month demand has been examined although the system may well operate throughout the year.

The top horizontal line on Figures 31a and 31b is the fuel oil value of the winter "heat" demand, presumably met by the waste heat recovery system. If SPC installed all the equipment in the user's building and their own building; installed the piping and operated the system; and charged the same rate as fuel oil heating value for the heat supplied, the profit or loss would be represented by the difference between the sum total of these costs and the value of the fuel oil replaced. Two crossover points are shown - one with the value of heat lost to the ground and one without.

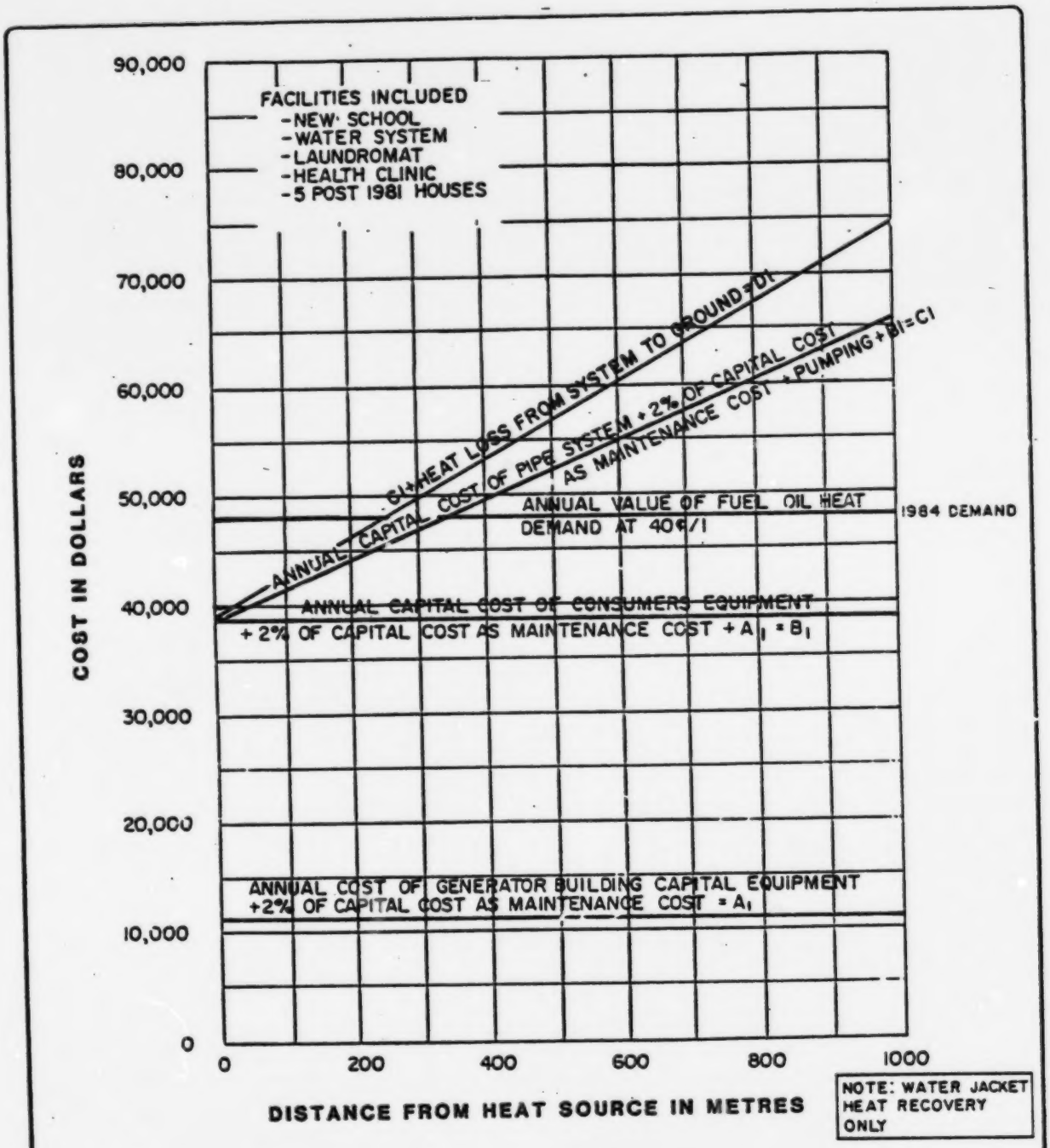
These graphs show that initially the heat recovery system will not be economical for Wollaston due to the distance between the school and the generation site.

These graphs indicate that consumer equipment has a large impact, confirming the original statement made in section 2 of this report - "desirable consumers are those with large single point loads". Each small building served has some of the same costs as a larger building. This is reflected in the service distance for the "total" group of users being approximately 350 metres from the source, while the economic service distance for the school, by itself, is approximately 600 metres.

It must be also noted that the graphs are based on a six month heating season. A longer heating season will improve the economics.

The fact that heat demand for the "full" service option may increase will have a significant impact. It is projected that demand will increase by $ 500 worth of fuel oil per year. Therefore, in 30 years, the simple economic service distance will be over 950 metres.

Also, if fuel costs increase at a rate greater than inflation, the economical service distance will also increase each year. For example, if fuel costs increase 2% more than inflation, in 15 years the



COST OF CONSUMPTION AND DELIVERY FOR DISTANCE FROM HEAT SOURCE

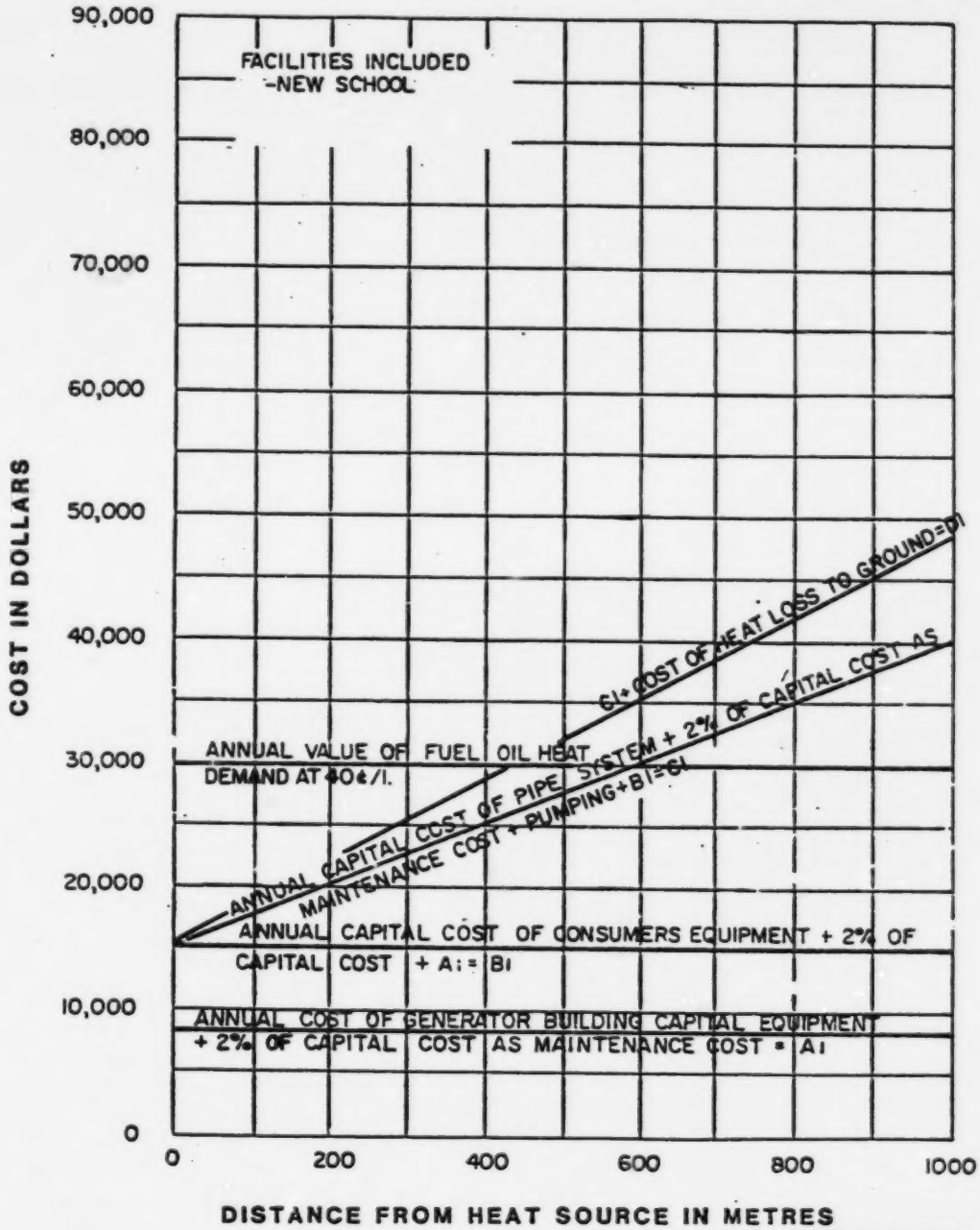
CLIENT/PROJECT
SPC CO-GENERATION STUDY

ASSOCIATED ENGINEERING SERVICES LTD

AES

SUBJECT

APPROVED | SCALE
DATE | DWG No. FIG. 31A
JOB No.



NOTE: WATER JACKET HEAT RECOVERY ONLY

COST OF CONSUMPTION AND DELIVERY FOR DISTANCE FROM HEAT SOURCE

CLIENT/PROJECT: SPC CO-GENERATION STUDY	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD — AESL	APPROVED / DATE / JOB No. / SCALE / DWG No. FIG. 31B

economical service distance of the school alone will have increased to 1000 metres.

Other variables affecting the economics of the system will be discussed in the economic analysis section.

The graphs can also be used to establish rates. The 13% discount rate incorporates a return on investment. Therefore, any surplus "profit" shown can be reflected in a decreased rate to make waste heat utilization attractive to the consumer. In addition, if the consumer supplies and maintains his own heat exchanger, the rate can be further reduced by the amount shown for user equipment capital cost.

Another item for future review is the economics of the gas heat recovery. A heat exchanger to recover waste heat from the water jacket will cost approximately $ 42,000 installed with pumps and piping ($ 7,000 for the exchanger alone). The flue gas heat exchanger is in the order of $ 65,000, installed. While desirable to provide peaking capacity for heating, it does not appear to be economically justifiable. The cost analyses have been prepared, assuming a flue gas heat exchanger will not be incorporated in any initial installations. It can be added later, if economically justifiable.

8.0 ECONOMIC ANALYSIS

In order to assess the economics of the project further, a present worth analysis was carried out. The variables of discount rate, inflation, fuel cost escalation, sensitivity to capital costs and revenue were examined.

A discount rate of 13% was used based on SPC's recommendations. To examine sensitivity, the capital costs were increased by 15%; annual expenses were increased by 20%; revenues were varied by 20% (six month heating season versus eight month heating season); and the project was deferred five years, in accordance with SPC guidelines. This analysis was done for heat supplied to the school only, plus heat supplied to school, the clinic, a laundromat, five houses, and the community water system.

Four variables were analyzed: capital cost; pumping costs; maintenance; and return on heat sales. Heat loss to the ground was not considered to affect cash flow. In both bases, 1000 metres of piping was assumed.

In each series of analyses, the inflation rates for capital, pumping, and maintenance costs were held at 7.8% (see discussion on inflation following this section). However, the cost of fuel oil was varied. Two runs were made - one with fuel oil costs increasing at 6% (SPC projections) and one with fuel costs increasing at 10% or 2.2% over inflation. Subsequently, at the request of SPC, a third run was made with fuel cost escalation equal to inflation.

The computer printouts of the analyses and the data used is in Appendix I. The data is from the cost tabled in the previous section of this report.

The following table summarizes the data on the computer printouts:

Table 6 - Present Worth Table

	All Facilities		School Only	
	6% Fuel	10% Fuel	6% Fuel	10% Fuel
8 month heating season	$ 256,940	$ 793,255	$ 132,199	$ 410,577
6 month heating season	160,273	617,137	77,331	315,685
6 month heating season with capital cost up 15%			46,525	284,878
6 month heating season with 15% capital cost and 20% operations and maintenance costs increase	75,123	532,123	29,821	268,174
6 month heating season with 5 year project deferral	85,198	582,741		

(Note: Project is assumed to have costs and revenue generation start in 1986. Five year deferral has start in 1991.)

It should be noted that the present value of the capital dollars for the full service concept and the school only concept is $ 320,074 and $ 202,039 respectively. If the projects do not have a value equal to or greater than these amounts, the money should be invested elsewhere.

If fuel costs escalate at a rate equal to inflation, the school only alternative is marginally economical for an 8 month heating season; the full service system is marginally economical for a 6 month heating season and improves for an 8 month heating season. For the school alone, the present worth of the system is $ 165,457 for a 6 month heating season and $ 235,312 for an 8 month heating season. For the full service option, the present worths are $ 328,047 and $ 454,089, respective y.

As inferred by the discussion in the previous section, the project only appears to be viable if fuel costs escalate at an amount over inflation for a service length of 1000 metres.

Fuel cost escalation seems to be the most sensitive variable.

8.1 INFLATION

The inflation rate was set at 7.8%, based on the average of the last 12 years of records for Regina and Saskatoon.

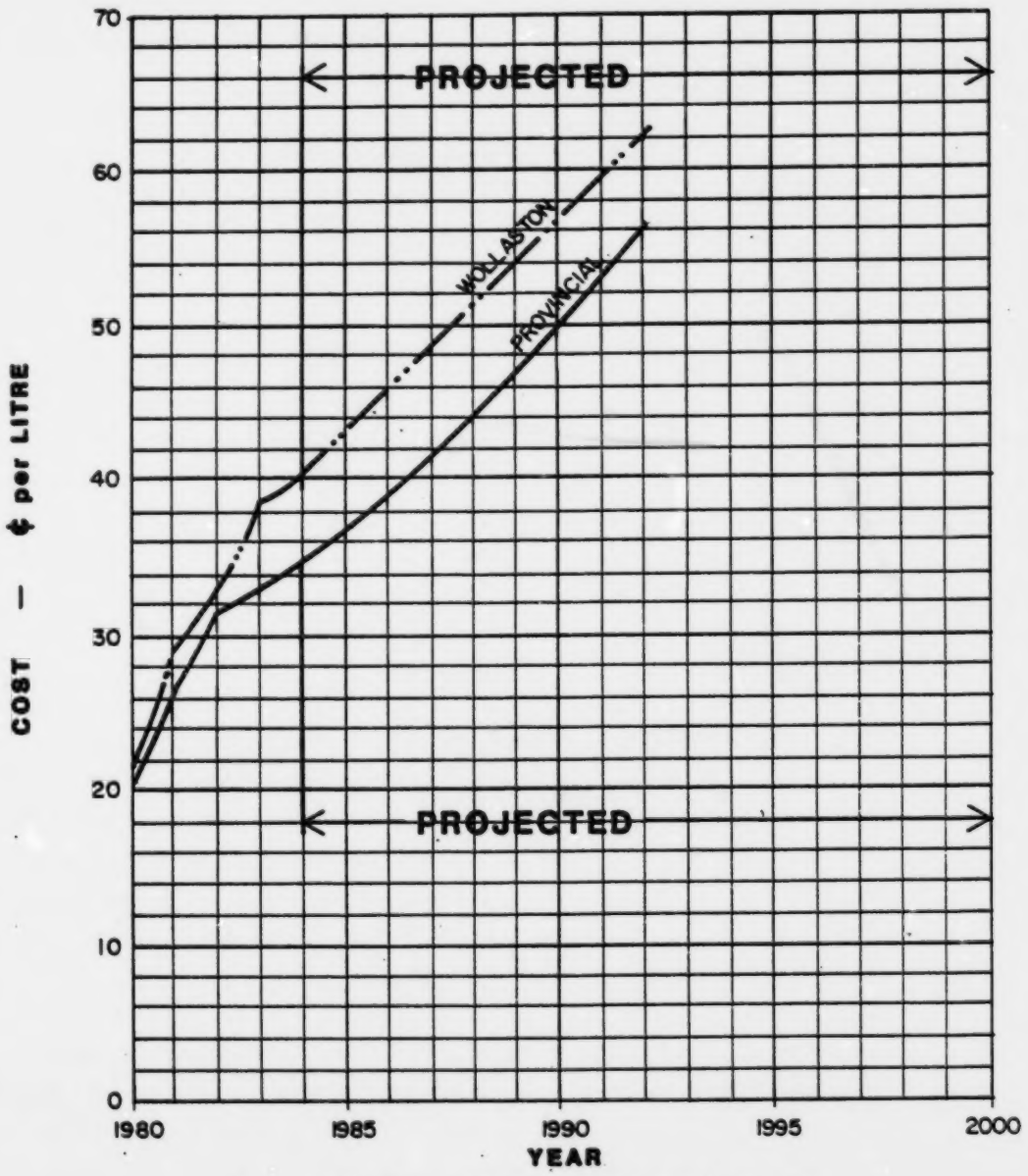
Table 7 - Inflation Table

Year	Inflation Rate	
	Regina	Saskatoon
1983	6.4	6.3
1982	9.0	8.9
1981	11.7	11.7
1980	10.1	10.5
1979	8.4	8.9
1978	9.1	7.8
1977	9.7	8.5
1976	8.6	8.2
1975	10.5	11.4
1974	9.4	9.3
1973	6.7	6.4
1972	4.6	4.6

8.2 FUEL COST ESCALATION

Fuel cost escalation, based on SPC's projections, is shown on Figure 32. These projections show that SPC does not expect the historical rapid increases in fuel costs to continue. Based on the 1983 to 1993 cost escalation, fuel costs will increase an average of 6% per year. As this is below the rate of inflation that has been used, an additional set of computer runs with fuel costs escalated at 10% per year were run to determine sensitivity.

The value of saved fuel has been taken as the equivalent amount of fuel that would have to be burned in an oil furnace to generate an equivalent amount of heat. This includes a 65% efficiency rating on the heat equipment. For example, when a value was placed on heat loss from underground piping, it was based on the amount of fuel a consumer would burn in his furnace to deliver an equivalent amount of heat to his structure.



FUEL COST PROJECTIONS

CLIENT/PROJECT **SPC CO·GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED / SCALE
	DATE / DWG No. **FIG. 32**
	JOB No.

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8.3 VALUE TO CONSUMER

The value of deliverable waste heat to the consumer will be different for different consumers. It will depend on the capital cost of heat recovery equipment to be installed; the amount to be paid for consumed heat; and the amount that can be potentially saved to offset the perceived inconvenience of a dual system. Other operating and psychological barriers will affect consumer acceptance and perceived value. Consumers will also potentially see the heat as surplus or "free" heat and object to paying fair market value for the heat. For consumer acceptance, the heat may have to be priced low enough to attract users to use it over conventional heating methods. This cannot readily be taken into account but can be reflected in the sensitivity analysis portion of the present worth in terms of reduced revenues.

8.4 VALUE TO SPC

The value of the waste heat to SPC is much easier to evaluate. The value for SPC is the excess annual income over annual cost. In this analysis, it is probably not appropriate to include the cost of heat lost to the ground as a cost once the optimum system is selected, unless this represents heat that otherwise could have been sold. This will not always be the case. The breakeven point for SPC will be when the annual operating and maintenance cost of the equipment and piped delivery system, plus the amortized capital cost equals revenue from heat sales. If SPC were to maintain ownership of the customer's heat exchanger, this would also be included. However, it is probably better to provide lower rates for the waste heat to give incentive to consumers to install and maintain their own equipment.

Assuming SPC installed and maintained all equipment, the present annual loss on an installed system at Wollaston Lake would be approximately $ 35,000 for a full system and $ 10,000 for the school alone on the basis of charging for heat at the equivalent cost for fuel oil. On the

otherhand, if the generating station was located within 200 metres of the school, and the school installed its own internal system, SPC could charge half of the current cost of fuel to the school for the heat and the school would net an immediate saving of approximately $ 10,000 after covering their costs.

8.5 POTENTIAL MARKET VALUE OF SURPLUS HEAT

The market value will be a value that will allow the consumer to save money by paying less per year for heating, including the amortization cost of extra equipment. This value will be the perceived value for the consumer. It will not necessarily bear a relation to whether or not SPC makes a return on their investment. Indeed, SPC could loose money or make money on the sale of heat with the market value remaining the same. The market value will increase with time and inflation since equipment installed today will provide heat at todays' costs rather than tomorrows' fuel costs. The market value of the heat will increase more rapidly than the cost of production. Increasing demand is also likely to increase the market value with time.

8.6 SENSITIVITY ANALYSIS

The high capital costs limit the economics of the system, particularly, in regards to the underground piping which is a sensitive area. Due to the remoteness of the site, construction costs are anticipated to be high. For example, excavation costs in Wollaston are projected to be approximately six times greater than in Regina (approximately $ 55 per linear metre versus $ 9 per linear metre). Capital costs for northern construction have been found to be highly variable.

Other areas of sensitivity include the interest rate, payback period, equipment replacement, maintenance, and market value of the heat, whether one considers the value of heat loss to the ground or the length of the heating season.

For the school, a supply distance of 1000 metres (refer to Annual Cost Table for Various Heating Alternatives) has a total annual cost of approximately $ 49,000, with the annual heat value set at $ 30,000. If we deduct the almost $ 9,000 included in "cost" for heat loss to the ground which is not a "cash" cost to SPC, the cost is immediately reduced to $ 40,000.

If we increase the length of the heating season to eight months from six, the extra pumping cost is only about $ 400, and the increased heat value will be about $ 5,000.

This leaves a $ 4,500 difference.

If we amortize the original capital costs over 30 years rather than 15 years, the annual capital costs will be reduced by almost $ 5,000. However, it can be expected that there will be some consumer and SPC equipment replacement over this 30 year period. Nevertheless, these "adjustments" can make the concept viable at 1000 metres.

Equipment maintenance, repair and parts replacements has been covered by a "rule of thumb" 2% of original capital cost assessment for maintenance.

A change in capital costs, up or down, has an immediate impact on the serviceability of the school at 1000 metres from the heat source.

The other major area of impact, relating to capital, is the interest rate. If 12% was used instead of 13%, an additional $ 2,000 per year would be cut from the cost.

Another area of sensitivity is the fuel oil value. In recent times, fuel oil costs have outpaced inflation. In this case, some additional revenue may be available to offset costs, and to recover replacement costs of equipment. However, fuel costs are presently falling.

However, as commented on previously, the market value of heat is not likely to be equivalent to the fuel oil price. Consumers must see potential savings if they are to be encouraged to use the waste heat. If costs are the same as fuel oil then there is no reason to change.

Consequently, the absolute limit of serviceability for the school at Wollaston is close to 1000 metres. This happens to be very close to the actual distance between the school and the proposed generating site. All other combinations of service are not immediately economical due to the cost of consumer equipment.

At 1000 metres the viability is extremely sensitive to capital cost, maintenance costs, market value of heat, length of heating season, interest rate and payback period.

Other combinations of service may be economical with time.

8.7 PAYBACK PERIOD

One area of sensitivity is the payback period. To justify energy related projects, periods of 2, 5, 10 and 15 years are often used. For the school only concept, if we look at the heat value less maintenance and pumping costs for a six month heating season, the money remaining to cover capital would be about $ 24,000 per year. At 13% interest on $ 221,000, this represents a payback period of over 60 years and is not deemed acceptable. Using an eight month heating period, the payback period is reduced to under 30 years. This demonstrates the impact the heating season and heat demand can have on the payback period. Service distance can have a similar impact. Actual payback would be less than this since inflation should increase revenue slightly over annual costs.

If the generating station could be located within 600 metres of the school, the payback would be less than 15 years for only a six month heating season. Sensitivity to other variables then becomes much less.

The payback period that is acceptable to SPC may be the determining factor on the viability of the project.

9.0 COMPARISON TO OTHER LOCATIONS

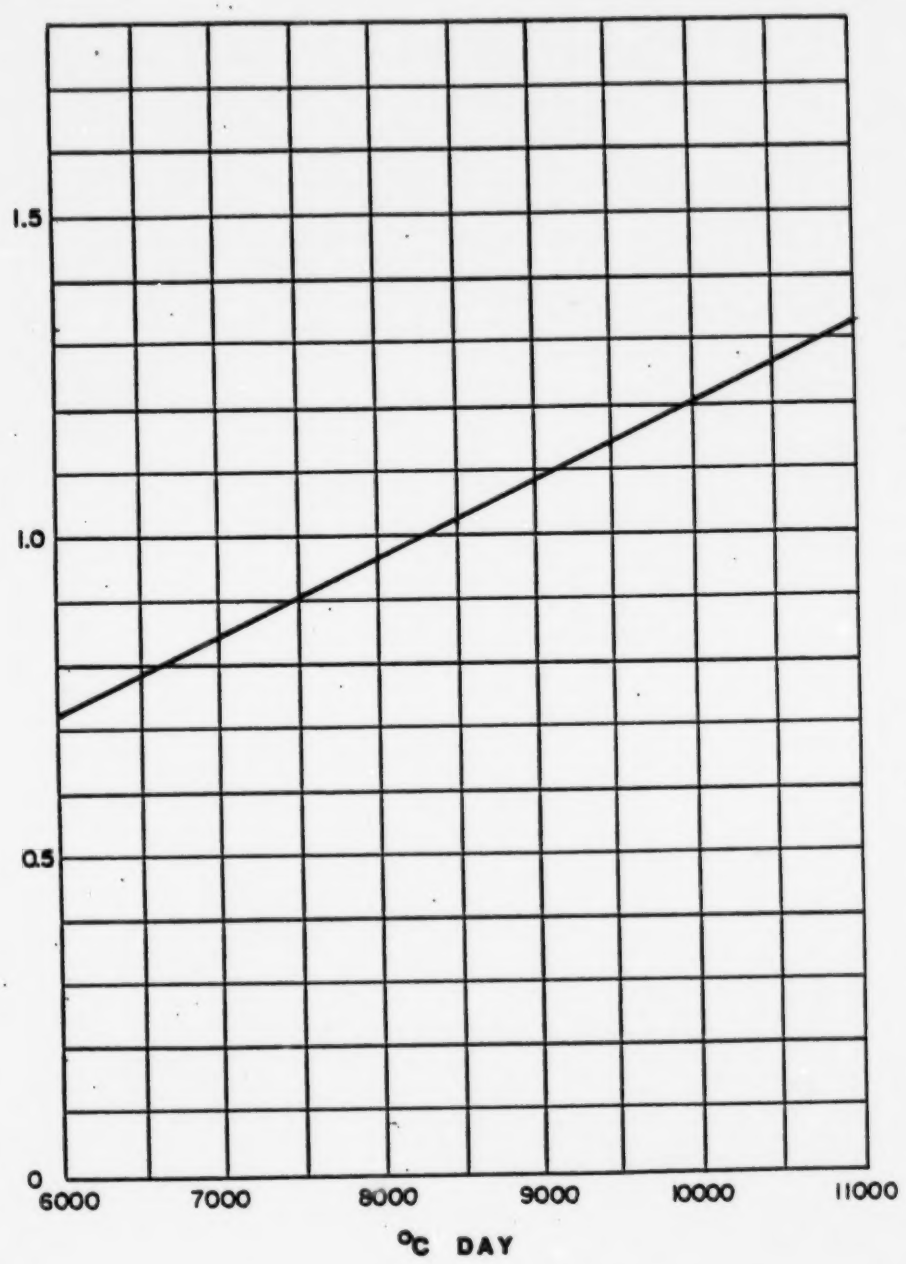
In order to transfer data developed for Wollaston to other locations, many of the figures and charts developed in the report were prepared in such a fashion as to allow their use to be universal. To further their use, some transformation and comparison figures were developed.

Figure 33 is a graph of heat loss factors versus degree days. This allows transfer of data for Wollaston to other areas if the degree day information is known. Figure 3 has degree day information for northern Saskatchewan. Figure 34 shows soil temperature envelopes for Wollaston, Cumberland House and Buffalo Narrows. As can be seen, and as would be expected, the soil temperature regime is most severe at Wollaston. Based on the conditions on Figures 34 and 3, conditions at Deschambault will be less severe than Wollaston; Stony Rapids will be similar to Wollaston; and at Southend they will fall in between these two.

Figure 35 illustrates the heat loss for the Wollaston school versus degree day information. Other schools of similar construction can be evaluated using this chart.

In terms of applicability of heat recovery to these other communities, Deschambault appears attractive, Stony Rapids has the same distance constraints as Wollaston, and Southend is probably not economically attractive.

At Deschambault, the school, proposed water treatment plant, arena with large heated area, and some teacherages are located within 150 metres of the generating station as shown on Figure 36. The school is smaller than the proposed school at Wollaston (2200 square metres versus 3000 square metres for the new school and 800 square metres for the old school). The temperatures would be more moderate. The existing school uses 25% more fuel oil and 4 1/2 times as much electricity as the existing school at Wollaston. However, the mean heat demand will be slightly less than at Wollaston. The generator demand is currently slightly less. Fuel costs are generally about



HEAT LOSS FACTORS vs DEGREE DAYS

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD	APPROVED DATE JOB No.
AES	SCALE DWG No. **FIG. 33**

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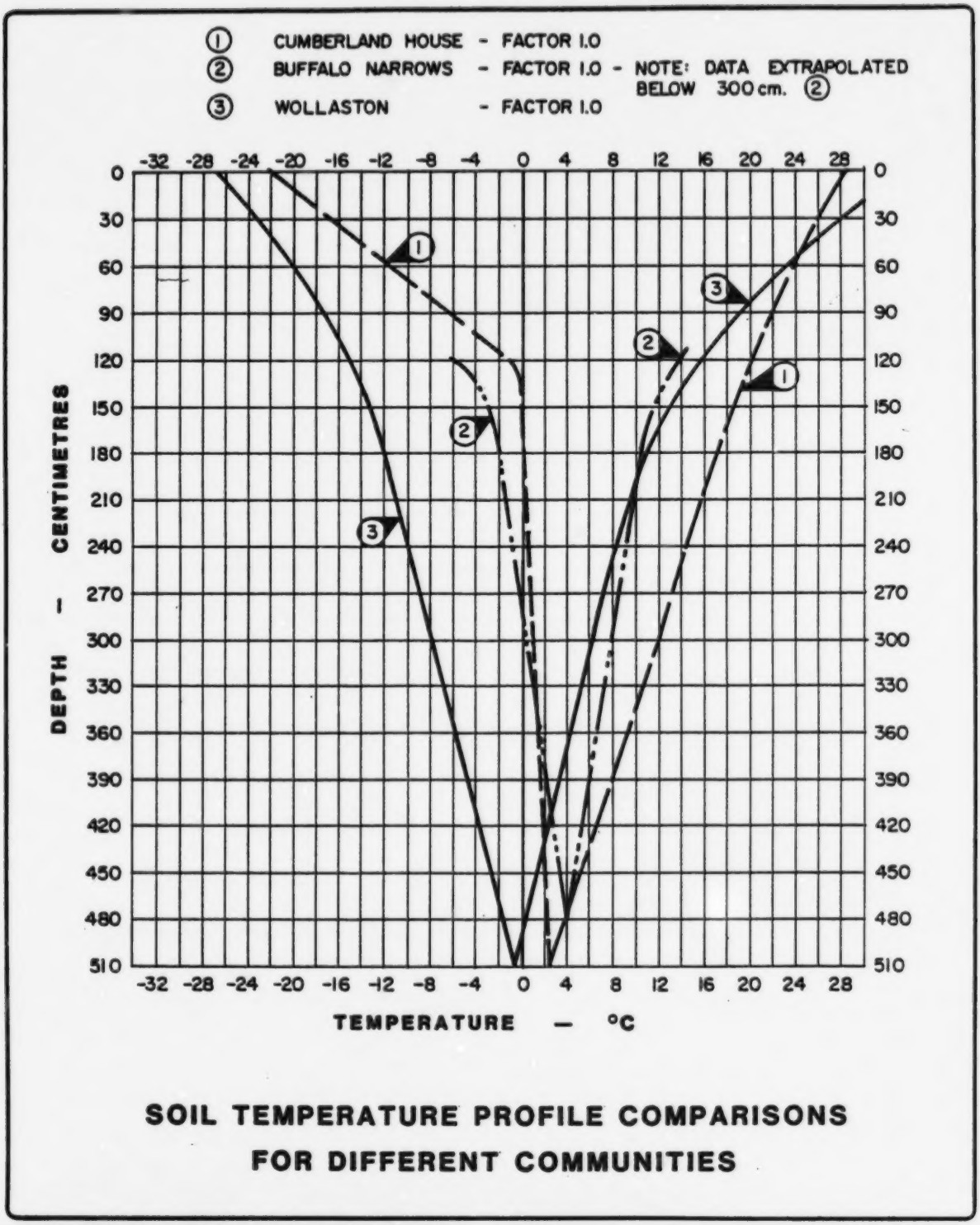
① CUMBERLAND HOUSE - FACTOR 1.0
② BUFFALO NARROWS - FACTOR 1.0 - NOTE: DATA EXTRAPOLATED BELOW 300 cm. ②
③ WOLLASTON - FACTOR 1.0
DEPTH - CENTIMETRES
TEMPERATURE — °C
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510

SOIL TEMPERATURE PROFILE COMPARISONS FOR DIFFERENT COMMUNITIES

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / SCALE
	DATE / DWG No. **FIG. 34**
	JOB No.

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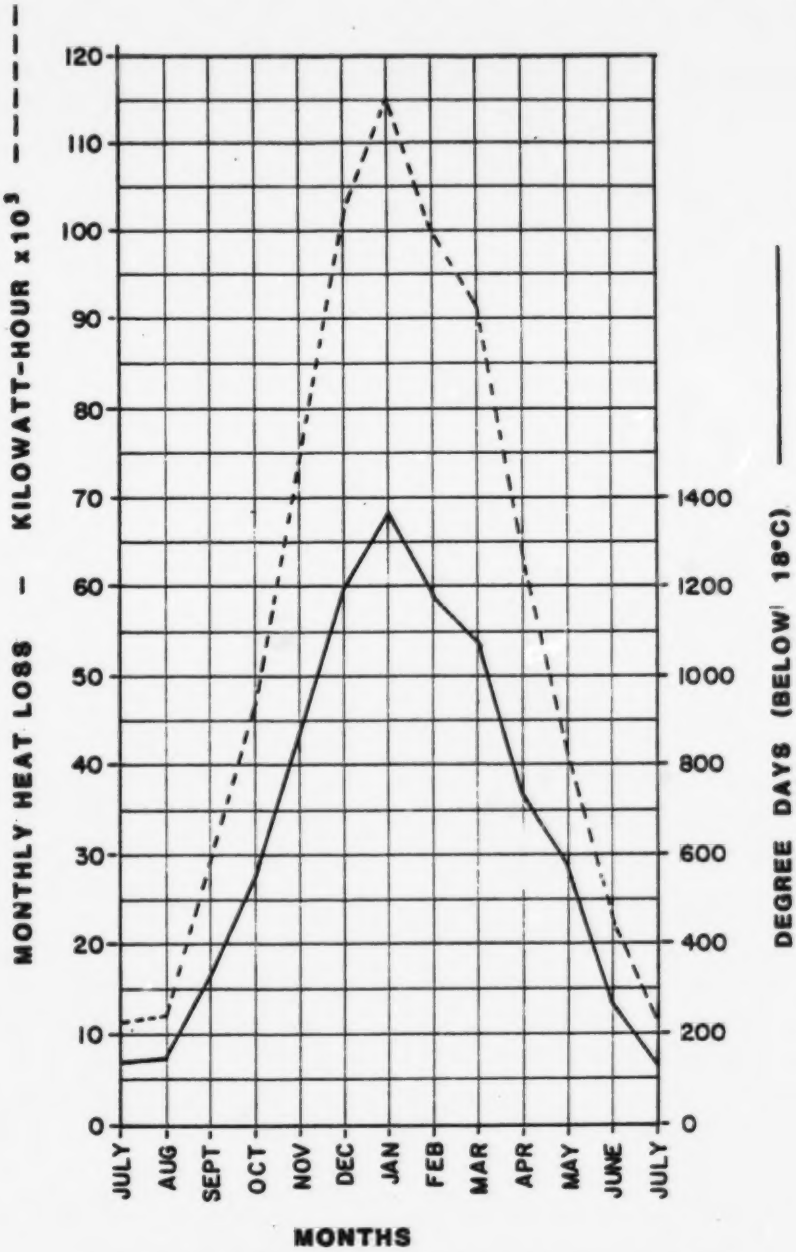

COMPARISON BETWEEN ESTIMATED NEW SCHOOL HEAT LOSS AND DEGREE DAYS

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / SCALE
	DATE / **FIG. 35**
	JOB No. RJ65

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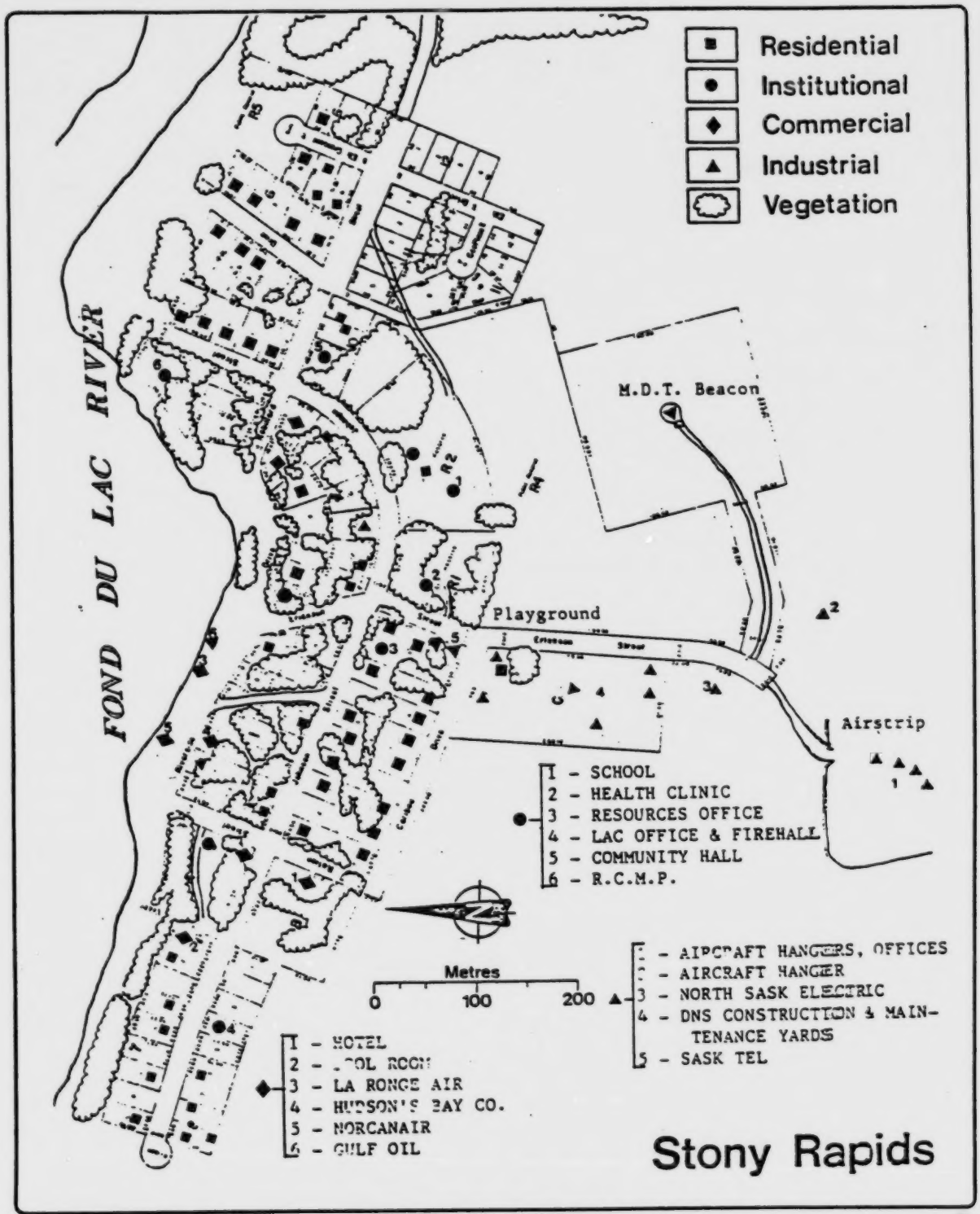
1¢ to 3¢ per litre less expensive at Deschambault than at Wollaston. Construction costs at Deschambault should be significantly less than at Wollaston Lake. However, without rigorous analysis, Deschambault Lake looks like an ideal candidate for water jacket only heat recovery to serve the school and water system heat loads, plus possibly a laundromat, the teacherages, and arena. The concentrated location of these loads is excellent. The existing school heating system would have to be reviewed before confirming this site's candicy for further review.

Conditions at Stony Rapids seem to lend themselves to waste heat supply. Fuel costs are high, 5¢ to 9¢ per litre more expensive than at Wollaston Lake. A school of about 2100 square metres exists approximately 1000 metres from the proposed generating site. A laundromat could be located adjacent to the heat supply line. Teacherages at the school site could be served. The health clinic, the water system, and some other industrial sites could be served. More electricity is generated than at Wollaston. However, the school is existing so the existing heating system may dictate some of the feasibility. Construction costs may be slightly more than at Wollaston. The educational facilities use about 40% more fuel oil per year than the existing facilities at Wollaston. It appears that Stony Rapids may be able to be economically serviced but more information is required. The community layout is shown on Figure 37.

The potential at Southend is not as good due to the long distance (1000 metres) between the generating site and the large 8600 (sic) square metre INAC school and teacherages. There are potential customers in the off-reserve area (see Figure 38). However, their loads are small compared to the potential school loads. The existing water system in the off-reserve area and the future Band water system could be served.

There is an anomoly in the data on Southend. The community energy profile indicates an 8653 (sic) square metre INAC school with 7 classrooms and 80 students; and an off-reserve school of 975 square metres with 124 students. A fuel oil demand of just slightly more than Wollaston is indicated for



CLIENT/PROJECT
SPC CO-GENERATION STUDY

SUBJECT

ASSOCIATED ENGINEERING SERVICES LTD

AESL

APPROVED	SCALE
DATE	DWG No. **FIG. 37**
JOB No.	

BCIL 5590A-AES

education facilities. The electrical demand in the education facilities is greater than the fuel oil demand. The electrical demand projected in the community is also disproportionately high. One might guess that there is an electrical heating load in the schools. The 8653 square metres is probably 865 square metres.

There are a number of potential consumers of waste heat. The distance to the large volume consumers may mitigate against development of a market in Southend. However, if the site is ever relocated, this could markedly change the situation.

The generalized graphs in the figures can be used for a preliminary evaluation of each location. In terms of community layout and potential consumers, the order of viability appears to be Deschambault, Stony Rapids, Wollaston and Southend.

10.0 CONCLUSIONS

10.1 AVAILABLE HEAT

There is sufficient heat available from the generator to provide the mean winter heating requirements for a large school and several other structures by using heat off the water jacket only. As the generator heat generation is not proportional to loading, a good portion of the peak heat loading requirements can initially be met by the water jacket heat. Available heat will increase with time due to increased electrical consumption, making more water jacket heat available for peaking requirements. If more heat is required, it can be obtained by recovering heat from the engine exhaust gases using a flue gas heat exchanger.

The only limit on available heat is the present control philosophy for the heating and ventilation of the generator building. The original design would waste a considerable amount of heat through the ventilation system. This has been addressed in the body of this report. If the operating philosophy is revised as recommended, heat demand at the generating station will be negligible. However, if it is not changed, the available heat would be inadequate for any large application.

10.2 DELIVERABILITY

The ability to deliver waste heat to the consumer is not limited by technical considerations. Adequate heat exchangers can recover heat from the diesel generators to serve the school and a number of other structures. Various heat exchangers are available to transfer the heat, to the structures.

Several insulated piping systems could be used to deliver the heat. Piping should be buried at a depth of approximately 1.5 metres. Insulation thickness should be 50 mm minimum. The cost effectiveness of thicker insulation needs to be reviewed.

The high cost of the insulated piping system limits the distance that heat can be economically delivered.

10.3 COST AND RETURN ON INVESTMENT

Several parameters affect the viability of this project. They include inflation, increase in demand for waste heat with time, fuel cost escalation, distance from heat source to consumer, capital costs, and operating and maintenance costs.

The most sensitive variables appear to be distance from source to consumer and fuel cost escalation.

In examining the costs and the viability of the project, some interesting items come to light:

a) For serving the new school alone, the initial crossover point for year one for economic servicing is for the school to be located approximately 600 to 800 metres from the heat source depending on the heating season length.

b) For serving the new school, east side water system, laundromat, health clinic and 5 houses; the initial crossover point for year one is approximately 350 to 500 metres from the school from the heat source depending on the heating season length.

c) The reason for this difference is due to the extra annual capital cost of the small consumers' heat exchangers being greater than the offsetting oil value for serving these structures.

d) Small residential loads carry a high unit cost that makes them marginal. The capital cost of consumers equipment in 1984 dollars to serve 5 houses is approximately $ 44,000. The annual capital cost will greatly exceed the annual value of saved fuel of $ 3,220 in 1984 dollars. It will take over 10 years for the annual fuel value to match the annual costs at a 7.8% inflation rate for fuel.

e) The layout at Wollaston leaves little margin to reduce heat cost to a point where there will be a saving over conventional fuel oil heating. Without demonstrated savings, there will be little justification for consumers to install a heat exchanger system utilizing waste heat.

f) Single, high load sources are the most desirable consumers.

g) The present worth of the estimated capital cost for serving the school alone, at 1000 metres from the generating station, is $ 202,039. With fuel cost equal to inflation and a 30 year cost recovery period, the net present value of the school system is estimated to be $ 165,457 for a 6 month heating season and $ 235,312 for an 8 month heating season. For the generating station located 1000 metres from the school, the system does not appear to provide an adequate return to risk the investment.

h) The present worth of the estimated capital cost for serving the school and other facilities, with the school being located 1000 metres from the generating station, is $ 320,074. With fuel cost equal to inflation and a 30 year cost recovery period, the net present value of the total system is estimated to be $ 328,047 for a 6 month heating season and $ 454,089 for an 8 month heating season. This places the total system at 1000 metres service distance into a marginally economical position based on several assumptions.

i) The assumptions that make the total system marginally economic are that heat demand will grow annually for the water system and laundromat, fuel costs will escalate at a rate equal to inflation, and the heating season will be between 6 and 8 months in length. Some of these assumptions are marginal. For example, in the last few years, fuel costs have escalated at less than inflation. Current projections indicate fuel costs will continue to escalate at less than inflation for the next few years.

j) Recovery of initial capital costs on the project at Wollaston could take up to 30 years.

k) The viability of the project would improve substantially if the generating facility were located closer to the school.

l) Use of high efficiency plate heat exchangers is desirable. This can reduce the size of the pipe required in the distribution system.

m) Optimization of components to minimize system flow is important and can lead to economies in equipment selection.

n) The use of flue gas heat recovery systems is marginal at best due to the high capital cost of flue gas (exhaust gas) heat recovery equipment.

o) Several specific changes to the current operating philosophy of the proposed generator building concept proposed for Wollaston needs to be made if this structure, or others like it, are to be used for district heat sources either at Wollaston or elsewhere. These modifications include:

- Modify control systems for heat exchangers 1 and 2 serving the generator building to provide direct control of secondary circuit temperature. Reuse the three-port valve as a safety bypass control to protect engine.

- Modify the control system for the generator building supply and exhaust systems. Install a low limit control on supply or operate building at a higher temperature.

- Reselect pumps to give required flow when both are operating. This gives a degree of flow dependability in the event of the failure of one pump.

- Wire low limit into starting circuit of exhaust fans to prevent them starting when the outside temperature is less than +5°C.

p) For new large structures such as schools, radiant floor panel heating is attractive due to the large thermal storage available and lower fluid temperature requirements when compared to air systems or even small hot water systems.

10.4 FUEL SAVINGS

For the school system to be served alone, a heat exchanger system could save in excess of 75000 litres of fuel oil per year. For the total system described, a heat exchanger system could save over 120000 litres of fuel initially, with an annual uncompounded increase in savings of approximately 2% per year.

The value of saved fuel is subject to market conditions. If fuel costs escalate below or equal to inflation, a heat recovery system for Wollaston is probably not justifiable. Should long term fuel costs increase faster than inflation, the project then becomes attractive. However, the current trend is for fuel cost escalation to be less than inflation.

10.5 APPLICATION OF FINDINGS TO OTHER SITES

1. Southend:

The major customers tend to be located even farther away from the Southend generating station than those at Wollaston. Construction costs at Southend will be less than at Wollaston but the poor apparent market at this time makes this site the least attractive.

2. Stony Rapids:

This site may have even higher construction costs than Wollaston. All construction materials must be delivered by barge on Lake Athabasca from Alberta, or by air. However, for these same reasons, fuel costs are likely to escalate more rapidly here. There appears to be a good market for waste heat within 1000 metres of the generating station. The generating station is larger than at Wollaston and could serve a large number of consumers from the water jacket heat. This site appears to have good potential for development of a district heating system.

3. Deschambault:

This is the most viable site. There are several potential major waste heat users located immediately adjacent to the generating facilities. The school is immediately across the street from the generating station.

Deschambault is relatively accessable and will have considerably lower construction costs than the other sites. Fuel costs are only maginally less.

Consequently, there is good potential for return on investment for SPC and potential for considerable savings in heating costs for the consumer at this site. However, there are plans for a new generating station at Deschambault. If it is constructed in a new location, the viability of using the waste heat may be placed in doubt.

4. Priorization of Development Sites:

Based on examination of the various sites, we priorize development as follows:

a) Deschambault;
b) Stony Rapids;
c) Wollaston Lake; and
d) Southend.

Deschambault appears to be immediately economic due to the short service length to major consumers. It can readily be staged. With considerable margin for error, it could be used as the pilot project for determining the viability of the other projects which appear marginal at this time. Selection of a new generating site should be made with waste heat utilization in mind.

10.6 ITEMS FOR FURTHER EXAMINATION AND STUDY

a) Detailed economics of certain aspects require more review - fuel costs, inflation, acceptable return on investment.

b) Deschambault should be examined in detail.

c) The potential for locating future generating sites as close as possible to the major potential users of waste heat needs review.

d) The potential for laundromat construction and use of a separate circuit for a laundromat located immediately adjacent to the generating facility should be addressed.

e) The potential for a swimming pool next to the generating facility heated with waste heat could be considered for utilization of summer waste heat.

f) Other uses of waste heat outside the normal heating season have not been considered in this study. Future studies may want to address this issue.

g) Failsafe devices may be desirable to prevent major system leakage from a customer's service. This has not been addressed in this report.

h) Expansion compensation in the buried pipe systems will have to be addressed in the detailed design or future studies.

i) The degree and economics of insulation thickness needs further consideration in future studies.

j) Better assessment of electrical demand and coincidence of heat demand and electrical demand is required. Appropriate metering should be considered for any projects carried out to confirm actual results with projections.

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CONVERSION FACTORS

Quantity	in	British or Common Unit†	× Factor	=	SI Unit
SPACE AND TIME					
Length		thou' (mil)	× 2·54 × 10^{-3} (E)*	= m	metre
			2·54 × 10^{1} (E)*	= μm	micrometre
		inch	2·54 × 10^{-2} (E)*	= m	metre
			2·54 × 10^{1} (E)*	= mm	millimetre
		foot	3·048 × 10^{-1} (E)*	= m	metre
		yard (British Standard)	9·144 × 10^{-1} (E)*	= m	metre
		mile	1·609 × 10^{3}	= m	metre
			1·609	= km	kilometre
Area		square inch	× 6·452 × 10^{-4}	= m^2	square metre
			6·452 × 10^{2}	= mm^2	square millimetre
		square foot	9·290 × 10^{-2}	= m^2	square metre
		square yard	8·361 × 10^{-1}	= m^2	square metre
		square mile	2·590 × 10^{6}	= m^2	square metre
			2·590 ×	= km^2	square kilometre
		acre	4·047 × 10^{3}	= m^2	square metre
			4·047 × 10^{-3}	= km^2	square kilometre
Volume		cubic inch	× 1·639 × 10^{-5}	= m^3	cubic metre
			1·639 × 10^{1}	= ml	millilitre
		cubic foot	2·832 × 10^{-2}	= m^3	cubic metre
			2·832 × 10^{1}	= *l*	litre
		cubic yard	7·646 × 10^{-1}	= m^3	cubic metre
		pint†	5·683 × 10^{-4}	= m^3	cubic metre
			5·683 × 10^{-1}	= *l*	litre
		gallon†	4·546 × 10^{-3}	= m^3	cubic metre
			4·546	= *l*	litre
		gallon (US)	3·785 × 10^{-3}	= m^3	cubic metre
			3·785	= *l*	litre
		litre	1 × 10^{-3} (E)*	= m^3	cubic metre
MOTION					
Velocity		foot/second	× 3·048 × 10^{-1}	= m/s	metre/second
		foot/minute	5·080 × 10^{-3}	= m/s	metre/second
		mile/hour	4·470 × 10^{-1}	= m/s	metre/second
		knot	5·148 × 10^{-1}	= m/s	metre/second
Acceleration		foot/second²	× 3·048 × 10^{-1}	= m/s^2	metre/square second
Frequency		cycle/second	× 1 (E)*	= Hz	hertz
MASS AND DENSITY					
Mass		ounce	× 2·835 × 10^{-2}	= kg	kilogramme
			2·835 × 10^{1}	= g	gramme
		pound	4·536 × 10^{-1}	= kg (4·535 923 7 × 10^{-1} E)	kilogramme
		ton	1·016 × 10^{3}	= kg	kilogramme
		ton (short)	9·072 × 10^{2}	= kg	kilogramme
		ton (metric)	1 × 10^{3} (E)*	= kg	kilogramme
		grain	6·479 × 10^{-3}	= kg (6·479 891 × 10^{-4} E)	kilogramme
			6·479 × 10^{1}	= mg	milligramme
Mass per Unit Length		pound/foot	× 1·488	= kg/m	kilogramme/metre
Mass per Unit Area		pound/foot²	× 4·882	= kg/m^2	kilogramme/square metre
Density (Specific Mass)		pound/foot³	× 1·602 × 10^{1}	= kg/m^3 = g/*l*	kilogramme/cubic metre = gramme/litre
		pound/inch³	2·768 × 10^{4}	= kg/m^3 = g/*l*	kilogramme/cubic metre = gramme/litre
		pound/gallon	9·978 × 10^{1}	= kg/m^3	kilogramme/ cubic metre = gramme/litre
Specific Volume		foot³/pound	× 6·243 × 10^{-2}	= m^3/kg	cubic metre/kilogramme

† All measures quoted are Imperial unless otherwise stated.
* E = Exactly.

Quantity	in	British or Common Unit†	× Factor	=	SI Unit
FLOW RATE					
Mass Flow Rate		pound/hour	× 1·260 × 10^{-4}	= kg/s	kilogramme/second
Mass Flow per Unit Area		pound/foot² hour	× 1·356 × 10^{-3}	= kg/m² s	kilogramme/square metre second
		pound/inch² hour	1·953 × 10^{-1}	= kg/m² s	kilogramme/square metre second
Volume Flow Rate		cubic foot/second	× 2·832 × 10^{-2}	= m³/s	cubic metre/second
			2·832 × 10^{1}	= l/s	litre/second
		cubic foot/minute	4·719 × 10^{-4}	= m³/s	cubic metre/second
			4·719 × 10^{-1}	= l/s	litre/second
		gallon/minute	7·577 × 10^{-5}	= m³/s	cubic metre/second
			7·577 × 10^{-2}	= l/s	litre/second
		gallon/hour	1·263 × 10^{-6}	= m³/s	cubic metre/second
			1·263 × 10^{-3}	= l/s	litre/second
		gallon/minute (US)	6·309 × 10^{-5}	= m³/s	cubic metre/second
			6·309 × 10^{-2}	= l/s	litre/second
		gallon/hour (US)	1·052 × 10^{-6}	= m³/s	cubic metre/second
			1·052 × 10^{-3}	= l/s	litre/second
		cubic metre/minute	1·667 × 10^{-2}	= m³/s	cubic metre/second
			1·667 × 10^{1}	= l/s	litre/second
		cubic metre/hour	2·778 × 10^{-4}	= m³/s	cubic metre/second
			2·778 × 10^{-1}	= l/s	litre/second
		litre/minute	1·667 × 10^{-5}	= m³/s	cubic metre/second
			1·667 × 10^{-2}	= l/s	litre/second
		litre/hour	2·778 × 10^{-7}	= m³/s	cubic metre/second
			2·778 × 10^{-4}	= l/s	litre/second
MOMENTUM					
Momentum		pound foot/second	× 1·383 × 10^{-1}	= kg m/s	kilogramme metre/second
Moment of Inertia		pound foot²	× 4·214 × 10^{-2}	= kg m²	kilogramme square metre
Moment of Momentum (Angular Momentum)		pound foot²/second	× 4·214 × 10^{-2}	= kg m²/s	kilogramme square metre/second
FORCE AND TORQUE					
Force (Weight)		pound force	× 4·448	= N	newton
		poundal	1·383 × 10^{-1}	= N	newton
		kilogramme force	9·807	= N	newton
		dyne	1 × 10^{-5} (E)*	= N	newton
Torque (Moment of Force)		pound force foot	× 1·356	= Nm	newton metre
PRESSURE AND STRESS					
Pressure		pound force/inch²	× 6·895 × 10^{3}	= N/m²	newton/square metre
			6·895 × 10^{-2}	= bar	bar
		pound force/foot²	4·788 × 10^{1}	= N/m²	newton/square metre
		kilogramme force/centimetre²	9·807 × 10^{4}	= N/m²	newton/square metre
			9·807 × 10^{-1}	= bar	bar
		inch H_2O(4°C)	2·491 × 10^{2}	= N/m²	newton/square metre
			2·491	= mbar	millibar
		foot H_2O(4°C)	2·989 × 10^{3}	= N/m²	newton/square metre
			2·989 × 10^{1}	= mbar	millibar
		millimetre H_2O(4°C)	9·807	= N/m²	newton/square metre
			9·807 × 10^{-2}	= mbar	millibar
		inch Hg(0°C)	3·386 × 10^{3}	= N/m²	newton/square metre
			3·386 × 10^{1}	= mbar	millibar
		bar	1 × 10^{5} (E)*	= N/m²	newton/square metre
		millimetre Hg	1·333 × 10^{2}	= N/m²	newton/square metre
			1·333	= mbar	millibar
		torr	1·333 × 10^{2}	= N/m²	newton/square metre
			1·333	= mbar	millibar
		atmosphere (standard)	1·013 × 10^{5}	= N/m²	newton/square metre
			1·013	= bar	bar
Pressure Drop per Unit Length		foot H_2O/100 feet	× 9·810 × 10^{1}	= N/m³(N/m²m)	newton/cubic metre
		inch H_2O/100 feet	8·176	= N/m³	newton/cubic metre
Stress		pound force/inch²	× 6·895 × 10^{3}	= N/m²	newton/square metre
		pound force/foot²	4·788 × 10^{1}	= N/m²	newton/square metre
		ton force/inch²	1·544 × 10^{7}	= N/m²	newton/square metre
		ton force/foot²	1·073 × 10^{5}	= N/m²	newton/square metre

† All measures quoted are Imperial unless otherwise stated.

Quantity	in	British or Common Unit†	× Factor	=	SI Unit
VISCOSITY					
Dynamic Viscosity (Absolute)		poise (dyne sec/centimetre²)	× 1	= Ns/m²	newton second/square metre
			1 × 10² (E)*	= cP	centipoise
		pound force second/foot²	4·788 × 10¹	= Ns/m²	newton second/square metre
			4·788 × 10⁴	= cP	centipoise
		pound force hour/foot²	1·724 × 10³	= Ns/m²	newton second/square metre
			1·724 × 10⁶	= cP	centipoise
		pound/hour foot	4·14 × 10⁻⁴	= Ns/m²	newton second/square metre
Kinematic Viscosity		stokes (centimetre²/second)	× 1	= m²/s	square metre/second
			1 × 10³ (E)*	= cSt	centistokes
		inch²/second	6·452 × 10⁻⁴	= m²/s	square metre/second
			6·452 × 10³	= cSt	centistokes
		foot²/second	9·290 × 10⁻²	= m²/s	square metre/second
			9·290 × 10⁴	= cSt	centistokes
		foot²/minute	1·548 × 10⁻³	= m²/s	square metre/second
			1·548 × 10³	= cSt	centistokes
		metre²/hour	2·778 × 10³	= cSt	centistokes
		Redwood No. 1 and No. 2 seconds	No direct conversion		
		SAE grades	No direct conversion		
TEMPERATURE					
Temperature. *See separate table, page* C7-25 C7-20					
HEAT					
Energy, Work, Quantity of Heat		British Thermal Unit (Btu)	× 1·055 × 10³ (see note below)	= J	joule (J = Ws = Nm)
			1·055	= kJ	kilojoule
		horsepower hour	2·685 × 10⁶	= J	joule
			2·685	= MJ	megajoule
		kilowatt hour	3·6 × 10⁶ (E)	= J	joule
			3·6 (E)	= MJ	megajoule
		therm (100 000 Btu)	1·055 × 10⁸	= J	joule
			1·055 × 10⁻¹	= GJ	gigajoule
		foot pound force	1·356	= J	joule
		metre kilogramme force	9·807	= J	joule
		kilocalorie (IT) (frigorie)	4·187 × 10³	= J	joule
			4·187	= kJ	kilojoule
		thermie	4·187 × 10⁶	= J	joule

Note. The British thermal unit is temperature dependent; for instance, the energy required to raise the temperature of one pound of water from 39°F to 40°F (Btu_{39}) is equal to 1059·52 joules, whereas the mean value over the range 32°F to 212°F (Btu_{mean}) is equal to 1055·79 joule. The International Steam Tables use a value of 1055·06 joule (Btu$_{IT}$) and this value has been used for all the conversions involving the Btu. On this basis one Btu$_{IT}$ per pound is equal to 2·326 × 10³ joule per kilogramme exactly.
The calorie is temperature dependent in the same way as is the Btu. For example, at 15°C it is equal to 4·1847 joules and at 20°C to 4·1808.
The mean calorie is equal to 4·18605 absolute joules and the calorie$_{IT}$ to 4·18689 absolute joules.
In addition the Calorie has been taken in practice to be equivalent to 1000 calories.

HEAT FLOW					
Power, Heat Flow Rate		Btu/hour	× 2·931 × 10⁻¹	= W	watt (W = J/s = Nm/s)
			2·931 = 10⁻⁴	= kW	kilowatt
		horsepower	7·457 × 10²	= W	watt
			7·457 × 10⁻¹	= kW	kilowatt
		horsepower (metric)	7·355 × 10²	= W	watt
		foot pound force/second	1·356	= W	watt
		ton refrigeration (12 000 Btu/h)	3·516 × 10³	= W	watt
			3·516	= kW	kilowatt
		kilocalorie/hour	1·163 (E)*	= W	watt
			1·163 × 10⁻³ (E)*	= kW	kilowatt
Intensity of Heat Flow Rate		Btu/hour foot²	× 3·155	= W/m²	watt/square metre
		watts/foot²	1·076 × 10¹	= W/m²	watt/square metre
		kilocalorie/hour metre²	1·163 (E)*	= W/m²	watt/square metre
Thermal Conductivity		Btu inch/hour foot² °F	× 1·442 × 10⁻¹	= W/m °C	watt/metre degree Celsius
		kilocalorie/hour metre °C	1·163 (E)*	= W/m °C	watt/metre degree Celsius
Thermal Conductance		Btu/hour foot² °F	× 5·678	= W/m² °C	watt/square metre degree Celsius
		kilocalorie/hour metre² °C	1·163 (E)*	= W/m² °C	watt/square metre degree Celsius
Thermal Resistivity		foot² hour °F/Btu inch	× 6·934	= m °C/W	metre degree Celsius/watt
		metre hour °C/kilocalorie	8·598 × 10⁻¹	= m °C/W	metre degree Celsius/watt
Thermal Resistance		foot² hour °F/Btu	× 1·761 × 10⁻¹	= m² °C/W	square metre degree Celsius/watt
		metre² hour °C/kilocalorie	8·598 × 10⁻¹	= m² °C/W	square metre degree Celsius/watt
Thermal Diffusivity		foot²/hour	× 2·581 × 10⁻⁵	= m²/s	square metre/second
		metre²/hour	2·778 × 10⁻⁴	= m²/s	square metre/second

† All measures quoted are Imperial unless otherwise stated.
* E = Exactly.

Quantity	in	British or Common Unit†	× Factor	= SI Unit	
HEAT ENERGY CONTENT					
Heat Capacity		Btu/°F	× 1·899 × 10³	= J/°C	joule/degree Celsius
		kilocalorie/°C	4·187 × 10³	= J/°C	joule/degree Celsius
Specific Enthalpy		Btu/pound	× 2·326 × 10³ (E)*	= J/kg	joule/kilogramme
			2·326	= kJ/kg	kilojoule/kilogramme
		kilocalorie/kilogramme	4·187 × 10³	= J/kg	joule/kilogramme
			4·187	= kJ/kg	kilojoule/kilogramme
Specific Heat Capacity (Thermal Capacity per Unit Mass)		Btu/pound °F	× 4·187 × 10³	= J/kg °C	joule/kilogramme degree Celsius
			4·187	= kJ/kg °C	kilojoule/kilogramme degree Celsius
		kilocalorie/kilogramme °C	4·187 × 10³	= J/kg °C	joule/kilogramme degree Celsius
			4·187	= kJ/kg °C	kilojoule/kilogramme degree Celsius
Entropy		Btu/°R	× 1·899 × 10³	= J/°K	joule/degree Kelvin
		kilocalorie/°K	4·187 × 10³	= J/°K	joule/degree Kelvin
Specific Entropy		Btu/pound °R	× 4·187 × 10³	= J/kg °K	joule/kilogramme degree Kelvin
			4·187	= kJ/kg °K	kilojoule/kilogramme degree Kelvin
		kilocalorie/kilogramme °K	4·187 × 10³	= J/kg °K	joule/kilogramme degree Kelvin
			4·187	= kJ/kg °K	kilojoule/kilogramme degree Kelvin
Latent Heat (Specific Energy)		Btu/pound	× 2·326 × 10³ (E)*	= J/kg	joule/kilogramme
			2·326	= kJ/kg	kilojoule/kilogramme
		kilocalorie/kilogramme	4·187 × 10³	= J/kg	joule/kilogramme
		foot pound force/pound	2·989	= J/kg	joule/kilogramme
Volumetric Calorific Value		Btu/foot³	× 3·726 × 10⁴	= J/m³	joule/cubic metre
			3·726 × 10⁻²	= MJ/m³	megajoule/cubic metre
		kilocalorie/metre³	4·187 × 10³	= J/m³	joule/cubic metre
			4·187 × 10⁻³	= MJ/m³	megajoule/cubic metre
Specific Heat (Volume basis)		Btu/foot³ °F	× 6·707 × 10⁴	= J/m³ °C	joule/cubic metre degree Celsius
			6·707 × 10⁻²	= MJ/m³ °C	megajoule/cubic metre degree Celsius
		kilocalorie/metre³ °C	4·187 × 10³	= J/m³ °C	joule/cubic metre degree Celsius
			4·187 × 10⁻³	= MJ/m³ °C	megajoule/cubic metre degree Celsius
MOISTURE CONTENT					
Vapour Permeability		pound foot/hour pound force	× 8·62 × 10⁻⁴	= kg m/Ns	kilogramme metre/newton second
			8·62 × 10³	= μg m/Ns	microgramme metre/newton second
		grain inch/square foot hour inch mercury (perm-inch)	× 1·45 = 10⁻¹²	= kg m/Ns	kilogramme metre/newton second
Vapour Permeance		pound/hour pound force	2·834 × 10⁻⁴	= kg/Ns	kilogramme/newton second
			2·834 × 10⁴	= μg/Ns	microgramme/newton second
		pound inch²/foot² hour pound force	× 1·965 × 10⁻⁷	= kg/Ns	kilogramme/newton second
		grain/square foot hour inch mercury (perm)	5·72 × 10⁻¹¹	= kg/Ns	kilogramme newton second
		grain/square foot hour millibar	1·94 × 10⁻⁹	= kg/Ns	kilogramme/newton second
Moisture Content		pound/pound	1	= kg/kg	kilogramme/kilogramme
		grain/pound	× 1·428 × 10⁻⁴	= g/kg	gramme/kilogramme
Moisture Flow Rate		grain/square foot hour	× 1·94 × 10⁻⁷	= kg/m²s	kilogramme/square metre second
		pound/square foot	1·357 × 10⁻³	= kg/m²s	kilogramme/square metre second
Mass Transfer Coefficient		foot/hour	× 8·47 × 10⁻⁶	= m/s	metre/second
LIGHT					
Luminous Intensity		candle (International)	× 9·810 × 10⁻¹	= cd	candela
Illumination		foot candle	× 1·076 × 10¹	= lx	lux
		lumen/foot²	1·076 × 10¹	= lx	lux
Luminance		foot lambert	× 3·426	= cd/m²	candela/square metre
		candela/inch²	1·550 × 10³	= cd/m²	candela/square metre
ELECTRICITY					
Already largely SI					

† All measures quoted are Imperial unless otherwise stated.
* E = Exactly.

APPENDIX A

DESIGN PARAMETERS

1. Climate:

Winter design temperature: -43°C
Annual degrees days: 8333 °C day

Monthly degree days:

January	1366	July	133
February	1175	August	142
March	1075	September	325
April	733	October	550
May	492	November	875
June	267	December	1200

Mean Daily Temperatures [°C]

January	-29	July	15.3
February	-26	August	14
March	-17.5	September	7.7
April	- 6	October	0
May	- 2.8	November	-12.8
June	10.8	December	-22.8

Mean Daily Minimum Temperatures [°C]

January	-34	July	10.5
February	-30.6	August	9.5
March	-24.6	September	3.8
April	-12.3	October	- 3.1
May	- 3.7	November	-16.9
June	5.5	December	-27.4

2. New School Construction 'R' Values:

- Walls	3.5 m^2 °C/W
- Roof	3.5 m^2 °C/W

Floor: (with perimeter insulation)

- Infiltration (classrooms)	1.0 AC/hr
- Ventilation (classrooms)	1.6 AC/hr
- Infiltration (gymnasium)	0.25 AC/hr
- Ventilation (gymnasium)	0.6 AC/hr

These figures are based on a design done several years ago for Pinehouse School.

DESIGN PARAMETERS, contd.

3. Old School Construction 'R' Values:

- Walls	1.23 m^2 °C/W
- Roof	1.23 m^2 °C/W
- Floor (no insulation)	

4. Health Clinic:

- Transmission loss	45 724 W
- Ventilation	33 120 W

These figures were obtained from the design engineer in Public Works Canada, Edmonton.

5. Generator Building:

Generator Room:	
- structure	15 kW
- infiltration	50 kW
Workshop/Washrooms:	17 kW

These figures were obtained from the designers in Saskatchewan Power Corporation.

The analysis of heat demand in the generator building is contained in Appendix M.

6. Residential:

Post-1981:

- Walls	1.8 m^2 °C/W
- Roof	3.5 m^2 °C/W
- Infiltration	1 AC/hr

Pre-1981:

- Walls	3.5 m^2 °C/W
- Roof	5.9 m^2 °C/W
- Infiltration	1 AC/hr

APPENDIX B

FORMULAE

1. Insulated Pipes: [Ref 4]

$$Q = \frac{2\pi\, ki\, (Tw - Tg)}{\ln (ri/rp)}$$

Where

Q = heat loss per unit length
ri = outside radius of pipe and insulation
rp = outside radius of pipe
ki = thermal conductivity of the insulation
Tw = temperature of the water in the pipe
Tg = temperature of the ground

Example

Ki = 0.0187 W/m°C
ri = 94.85 mm
rp = 44.45 mm
Tw = 71°C
Tg = -14.7°C

$$Q = \frac{2 \times 3.1416 \times 0.0187\, (71 - (14.7))}{\ln(94.85/44.45)}$$

$$= 13.29 \text{ W/m}$$

FORMULAE, contd.

2. Heat Metering:

Heat transferred = $\frac{\text{mass}}{\text{sec}}$ x specific heat x temperature difference

Where $\frac{\text{mass}}{\text{sec}}$ = volume $\frac{L}{s}$ x density $\frac{kg}{L}$

$Q = V \cdot p \cdot Cp \cdot \Delta t$

Where

Q = heat transferred
V = volume of heating liquid flow
p = density of heating liquid
Cp = specific heat of heating liquid

Example

V = 5.89 L/s
p = 0.9775 kg/L (water at 70°C)
Cp = 4.191 kJ/kg°C
Δt = 25°C

$$Q = (5.89 \frac{L}{s})(0.9775 \frac{kg}{L})(4.191 \frac{kJ}{kg°C})(25°C)$$

= 603 kW

Cp = 3.77 kJ/kg°C for 50/50 glycol solution

If this load is maintained for one hour, the total heat delivered

= 603 kW x 1 hr

= 603 kW·h

FORMULAE, contd.

3. Monthly Heating Energy Consumption: [Ref 5]

Modified degree day procedures

$$E = \left(\frac{Hl \times D \times 24}{\Delta t \times n \times V}\right)(Cd)(Cf)$$

Where

E = energy consumption for the period
Hl = design heat loss, including infiltration
D = number of degree days for the period below 18.3°C
Δt = design temperature difference
n = rated full load efficiency, decimal
V = heating value of fuel
Cd = correction factor for heating effect versus degree days
*Cf = part load correction factor (for fueled systems only)

$$\text{Energy consumption} = \left(\frac{Hl \times D \times 24}{\Delta t}\right)(Cd)\ kW{\cdot}h$$

Example

Hl = 190 W/m^2 (house)
D = 1366°C days (January)
Cd = 0.48

$$E = \left(\frac{190\ \frac{W}{m^2} \times 1366°C\ \text{days} \times 24\ \frac{hr}{days}}{65°C}\right)(0.48) \times \frac{1}{1000}\ \frac{kW}{W}$$

$$= 46\ kW{\cdot}h/m^2$$

*Cf - part load correction factor ignored because of the different methods of heating buildings.

Heat loss versus degree days interim factor [Cd]:

Outside design temperature [°C]	-43	-29	-23	-18	-12	- 7
Factor [Cd]	0.48	0.57	0.64	0.71	0.79	0.89

APPENDIX C

SPACING OF COMPENSATORS

Assume pipes are installed during the summer months at a depth of 1.5 metres.

From the soils temperature profile computer printout, the soil temperature is 0°C.

Maximum hot water temperature assumed at 80°C

$\therefore \Delta t$ max = 80°C (144°F)

At this Δt, steel pipe will expand 1:960 (1.25 in per 100 ft)

Because it is very likely that any contractor who undertakes this project will have little or no experience with expansion loop installation, it is assumed that expansion loops are installed with no "cold draw".

Each expansion loop would consist of a length of pipe plus 4 x 90° elbows. This means at least 8 welds, plus 3 pipe cuts per loop.

Since welding and fittings are known to be very expensive in relation to pipe price, there must be a point at which the price of installing a loop balances with the extra price of pipe required for spacing loops further apart. Also, the physical room required for these loops must be considered.

Approx. cost of 6 ft dia loop:

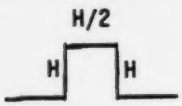
4 x 90° insulated weld elbows @ $ 130.00	$ 520.00
8 welds @ $ 10.00/dia in/weld (8 x 60)	480.00
3 pipe cuts @ $ 2.50/dia in/cut (3 x 15)	45.00
Total:	$ 1,050.00

This is a fixed cost per loop, plus pipe for the loop, plus trench excavation and backfill.

Consider approx. 100 m (328 ft) spacing

Expansion = 3.28 x 1.25 = 4.1 in (104 mm)

From tables (Ricwil catalogue, for Grade B steel), the total amount of pipe required in the loop is approx. 39 ft and the length of the leg is $\frac{34}{2.5}$ 13.6.



The top of the loop (H/2) cannot be considered as extra pipe since it would be required anyway.

∴ extra pipe required = 2H = 2(13.6) = 27.2 ft = 8.3 m

Cost of 6 in dia pipe complete with 2 in approx. $ 60/m

8.3 x $ 60 = $ 498

Cost of trench excavation and backfill (from projections) for 1.5 metres depth approx. $ 52/m

8.3 x $ 52 = $ 432

∴ total cost of loop approx. $ 1,050 + $ 498 + $ 432 = $ 1,980

Using Wehotherm® allowable expansion for expansion compensators, size 168 mm is 110 mm

$\frac{110}{25.4}$ = 3.98 in

∴ the <u>absolute maximum</u> length between compensators is 100 m on 6 in dia pipeline

The cost of this compensator is given as approx. $ 1,300, plus two welds @ $ 60/weld = $ 120

∴ total approx. $ 1,420

If the expansion loops were placed at 150 m (approx. 500 ft), the length of pipe in the loop required is 48 ft.

The length of the offset required is $\frac{48}{2.5}$ = 19.2 ft (5.85 m)

∴ the cost would be approx. $ 1,050 + (11.7 x 60) + (11.7 x 52)

approx. $ 2,460

∴ in a 1000 m run to the school, required 2000 m of pipe

Expansion loops @ 100 m = $\frac{2000}{100}$ x 1,980 = $ 39,600 = 19.8/m

Expansion compensators @ 100 m = $\frac{2000}{100}$ x 1,420 = $ 28,400 = 14.2/m

Expansion loops @ 150 m = $\frac{2000}{150}$ x 2,460 = $ 32,800 = 24.60/m

Although spacing of expansion loops at intervals greater than 150 metres is possible and would begin to become less expensive than compensators, there are several factors which make this unattrative. These are:

a) The length of offset legs required become large and will require right-of-way to install and service; (This right-of-way would be quite large and wasteful.)

b) The more length of pipe and fittings that are added, the more it costs to run the system from the standpoint of pumping cost and heat loss from the pipe; and

c) The more fittings and joints there are, the greater the chances of problems.

The most satisfactory installation is the type which uses self-compensating slip type joints on the pipe ends themselves. However, this type of pipe appears to be far more expensive than the other options available.

Self contained expansion compensators with external guides appear to be the most satisfactory. Additional design information is required on their use, particularly, with respect to the axial thrusts produced.

Steel Pipe:

Assume pipe is standard Grade B - tensile = 30 000 psi

$\therefore$ s all = 15,000 psi

Assume pumping pressure = 75 psi max
Assume all pipe is standard weight

Stress due to internal pressure:

$$St = \frac{pd}{2t}$$

For 25 mm (1.069 in): t = 0.133

$$St = \frac{(75)(1.069)}{2(0.133)} = 301 \text{ psi}$$

For 50 mm: t = 0.154

$$St = \frac{(75)(2.067)}{2(0.154)} = 503 \text{ psi}$$

For 65 mm: t = 0.203

$$St = \frac{(75)(2.469)}{2(0.203)} = 456 \text{ psi}$$

For 75 mm: t = 0.216

$$St = \frac{(75)(3.068)}{2(0.216)} = 532 \text{ psi}$$

For 100 mm: t = 0.237

$$St = \frac{(75)(4.026)}{2(0.237)} = 637 \text{ psi}$$

For 150 m: t = 0.280

$$St = \frac{(75)(1.069)}{2(1.065)/(9)(0.280)} = 812 \text{ psi}$$

APPENDIX D

GENERAL SYSTEM DESIGN CONSIDERATIONS

A. Primary Circuit:

The primary circuit comprises a liquid to ~~li~~quid heat exchanger, gas to liquid heat exchanger, piping, valves, controls, and connections to the engine coolant system to the externally mounted radiator.

The coolant proposed is 50/50 propylene glycol/water solution.

With the enlarging of the primary circuit and the operation of the system at a 102°C flow temperature, if heat is recovered from the exhaust gases, it is possible that the expansion tank provided with the radiator will have to be enlarged to accept the additional volume or the system will have to operate at a pressure higher than 50 kPa, the present operating pressure. This has to be checked with the engine manufacturer at the time of final design.

1. Liquid to Liquid Heat Exchanger:

The principal heat exchanger shall be a plate heat exchanger, chosen for its compact size, low weight, and high efficiency with heat transfer rates two or three times greater than a shell and tube exchanger for the same operating conditions. This gives approach temperatures very close to entering primary temperatures depending on the flow rate, pressure drop, and number of plates chosen.

a) Jacket and Flue Gas Recovery:

Heating exchanger duty: 890 kW

Primary Conditions:		Secondary Conditions:	
Flow rate	16.2 L/s	Flow rate	8.6 L/s
Inlet temp.	101°C	Inlet temp.	56°C
Outlet temp.	86.4°C	Outlet temp.	83.5°C

b) Jacket Recovery:

Heat exchanger duty: 570 kW

Primary Conditions:		Secondary Conditions:	
Flow rate	16.2 L/s	Flow Rate	7.0 L/s
Inlet temp.	94.4°C	Inlet temp.	56°C
Outlet temp.	85°C	Outlet temp.	78°C

Manufacturer: Alfa Laval, Peterborough, Ontario

The peak demands of the buildings examined total 890 kW.

The peak recoverable heat off the jacket plus muffler is 970 kW. Therefore, demand would be met if the engine were running at 100% electrical demand.

The peak recoverable heat of the jacket alone is 570 kW. Therefore, peak school demand would be met at the same operating condition.

2. Gas to Liquid Heat Exchanger:

This is used to recover heat from the exhaust gases.

Flow must be ensured through the recovery unit whenever the engine is running. This means that the engine thermostat and bypass be removed. During the summer, if it is not in use, the exchanger must be isolated and a bypass vent installed. During the design process, the hydraulic characteristics of the primary circuit with the exchangers, control valves, and radiator need to be checked as the pump on the engine may not be able to develop sufficient head to circulate sufficient liquid to limit the temperature rise to 8°C across the engine.

The back pressure of 500 Pa is well within the permissible back pressure of 6.7 kPa.

a) Gas Side:

Heating duty: 400 kW

Entering gas temp.	500°C
Leaving gas temp.	163°C
Mass flow at full load	3943 kg/hr

b) Liquid Side:

Flow rate	16.2 L/s
Entering glycol temp.	94.4°C
Leaving glycol temp.	101°C

Manufactuer: Riley Beaird, Shreveport, Louisiana

This unit is to be separated from the exhaust vent by means of suitable expansion compensators.

This unit is to be insulated with a minimum of 2 inches calcium silicate insulation.

Initially, while only one engine is operating at any one time, one heat exchanger can be used for both engines providing it is mounted on a common bypass. The vent and pipe connections would have to be valved off as required. The structure would have to be checked for a suitable supporting method as the operating weight of the unit is approximately 2240 kg. A steel structure on legs could be mounted above the engines to support the present exchanger and new vent piping. Lifting tackle would be required to withdraw the tube bundle for cleaning.

3. Piping:

This shall be carbon steel ASTM 53, Grad B, Schedule 40, size 100 mm. Insulation shall be a minimum of 50 mm thick fibreglass with canvas cover. Flexible joints are to be used were connections are made to the engine.

4. Valves:

All valves shall have rising stems.

Flanged valves shall be used on sizes greater than 65 mm.

Valves on pump discharges shall be the circuit settler type as manufactured by Taco or Bell & Gossett with characteristic plug and pressure tappings.

Check valves shall be mounted on the discharge of parallel operating pumps to prevent circulation if one pump should fail.

Alternatively, Taco "Plus one" multi-purpose valves can be used in place of the check valves and circuit setters.

Pressure relief valve shall be located at the outlet from the flue gas heat exchanger.

5. Pumps:

These shall be in-line centrifugal pumps electrically driven.

Pumps shall operate in pairs where shown to provide the total flow at the system head.

A differential pressure gauge shall be provided.

Operating curves shall be frame mounted adjacent to pumps for reference with design operating point clearly marked.

a) Subprimary:

Two Taco Model 1641 3 hp 8.1 L/s

b) Secondary:

School: Two Taco Model 1635 1.5 hp 5.5 L/s

Laundromat: Two Taco Model 133 3/4 hp
One Taco Model 112 1/3 hp

Water Heating: Two Taco Model 113c 1/8 hp

Health Clinic: Two Taco Model 113 1/8 hp

These are provisional sizes. The designer must check hydraulic head once system has been designed.

B. Expansion Facilities

1. Liquid:

The size, length and operating temperatures of the secondary system have a direct bearing on the expansion volumes that must be received by an expansion tank.

The system expansion volumes were calculated for 2000 metres of 100 mm and 150 mm diameter pipe at an average operating temperature of 73°C.

The expansion tanks required are as follows:

100 mm diameter pipe	One CA 1400 Taco
150 mm diameter pipe	Two CS 1400 Taco

These tanks are selected to provide a fill pressure of 140 kPa. The tank will maintain the system pressure at 410 kPa on the suction side of the pump.

Associated with the expansion tanks is an air separator with release to remove any air in the system as the system heats up.

2. Piping:

See Appendix C - Spacing of Expansion Compensators.

3. Secondary Side Piping (buried) and Insulation:

Various piping systems were examined - polyethylene, copper and steel.

Steel was chosen because of its cost and durability.

Two steel pipe joint systems were examined - push-on and welded.

The pipe system chosen was welded steel by Shaw Pipe Protection Ltd. with 50 mm insulation.

Technical data on manufacturers' systems is contained in Appendix E, F, G and H.

4. Heat Meters:

The quantity of heat used to heat a building is a function of the mass flow rate of water, its specific heat, and temperature drop across the heating circuit.

Water flow is measured by a multiple wheel water meter with totalizers. A pulse transmitter on the meter sends pulses to a remote heat meter.

Flow and return temperatures are sensed by a matched pair of resistance sensors located in the flow and return pipes of the system and the temperature signals are then transmitted to the heat meter. The degree of accuracy of the sensors is a function of the temperature difference across the heating circuit.

The sensor signals are converted into pulse length proportional to the temperature differential. The heat meter multiplies the pulse length by the pulse quantity and computes the heat quantity considering the variation in density and specific heat of water.

The integrator should be mounted clear of electrical interference fields, shielded from excessive radiation off equipment. The flow into the meter should be straightened to ensure good flow measurement.

Technical information is included in Appendix I.

Manufacturers and Suppliers:

Valmet Meter Works, Finland
(Aalto Inc., Toronto, Ontario 416-484-0729)

Sonceboz Corporation, U.S.A.
(Flocrest Equipment, Winnipeg, Manitoba 204-633-0687)

Aquametro AG, Switzerland
(Ranger Instrument Co., Basingstoke, England 011 44 256 64911
Telex 858318)

5. Future System Expansion:

a) Primary:

When it becomes necessary to operate both engines to meet the peak loads, a second exhaust recovery muffler would be required with interconnection with the existing vent system.

It is understood that only two engines will be equipped with heat recovery.

b) Secondary:

The flow rates were determined to meet the peak instantaneous demands of the buildings connected.

With the expansion of the system to other buildings, the main secondary pumps would require to be changed. If this is not done, the major consumer, such as the school and laundromat, would have to accept less flow for a time dependant on the degree of expansion. This is not as critical as might first appear as the heat exchangers for both these buildings have extra heating surface. If the water temperature returning to the secondary is too low, resulting in a drop in primary return temperature back to the engine, the primary flows to the secondary exchanger will reduce. This will be reflected throughout the whole system.

It is not foreseen, at this stage, that small additions to the system, by themselves, will have a major impact on the system.

If major additions can possibly be identified at this stage, they will have a definite influence on whether the mains should be 100 mm or 150 mm diameter since as the flow rate increases, the 150 mm diameter pipe becomes more economical.

C. Operating and Maintenance Considerations:

1. Engines:

The existing engines receive regular maintenance four times per year from Saskatchewan Supply and Services, Maintenance and Repairs Branch in Prince Albert.

Local operators are responsible for starting and stopping the machines and performing oil changes.

The detailed operation and maintenance instructions for these engines is contained in Caterpillar's instructions SEBU5690-01 for the D398 generator set engines.

The following points are emphasized:

a) Check the specific gravity of the glycol and compare readings with laboratory calibration curve; and

b) Check concentration of corrosion inhibitor.

Both should be carefully checked whenever water is added to the system.

2. Flue Gas Heat Exchanger:

This exchanger requires virtually no attention during its operation. Care must be exercised by the operator to ensure that there is always fluid flow through the unit when the engine is running.

To facilitate this:

a) Use rising stem isolating valves;

b) Check the operation of the pressure relief valve by discharging the valve into a container for collecting and storing glycol released from the system; and

c) Connections should be inspected periodically for leakage.

Prolonged use will result in the deposition of soot on the heat transfer surface which will reduce heat transfer. This has to be removed.

Methods suggested by the manufacturer are as follows:

a) Inject low temperature activated soot removal powders ahead of the unit while the engine is on partial load and the unit is dry; or

b) Remove body section exposing the outlet end of the tube bundle and clean with compressed air or remove bundle for brushing.

This should be done at the end of a heating season. Some water treatment may be required in the primary circuit. Advice should be sought from a water treatment specialist as to tests required.

3. Main Secondary Heat Exchanger:

Since this is a plate type exchanger, little maintenance is required. When cleaning is required, the covers can easily be rolled back for plate inspection cleaning or replacement.

4. Pumps:

These should be checked periodically for operation. Pressure gauges across the pump will quickly show if there has been an increase in flow by one pump due to the failure of the other pump.

5. Heat Meters:

These do not require maintenance. If they are being used for billing purposes, they should be returned periodically to the manufacturer or tested on-site with a test kit. Batteries should be replaced every six years.

6. User Equipment Operation:

Depending on available heat, the consumer's backup fuel oil system may only function during very cold conditions or when electrical demand is low. Consequently, the user should operate his fuel burning equipment weekly for a few hours to ensure that operational readiness is maintained.

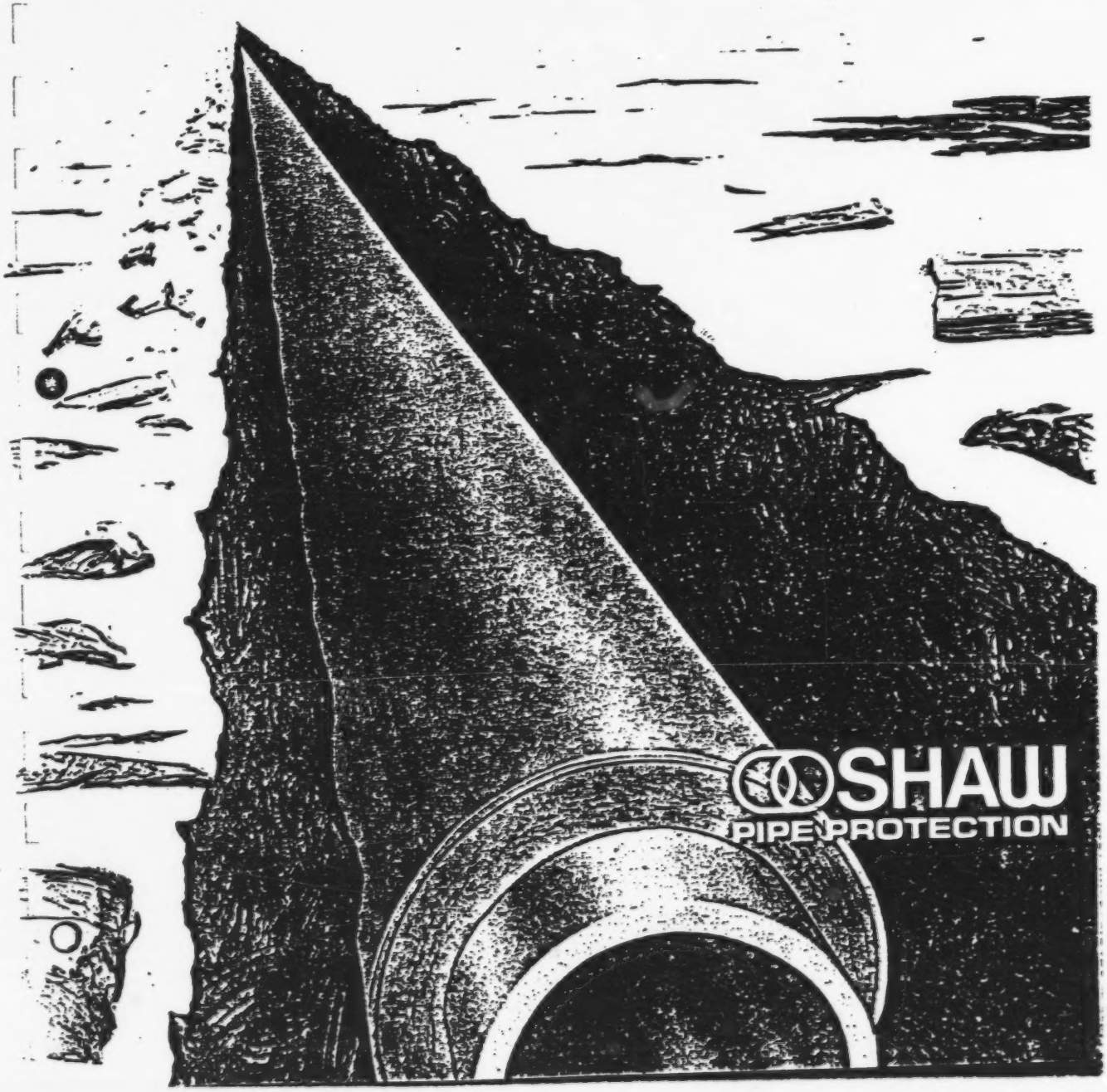
APPENDIX E

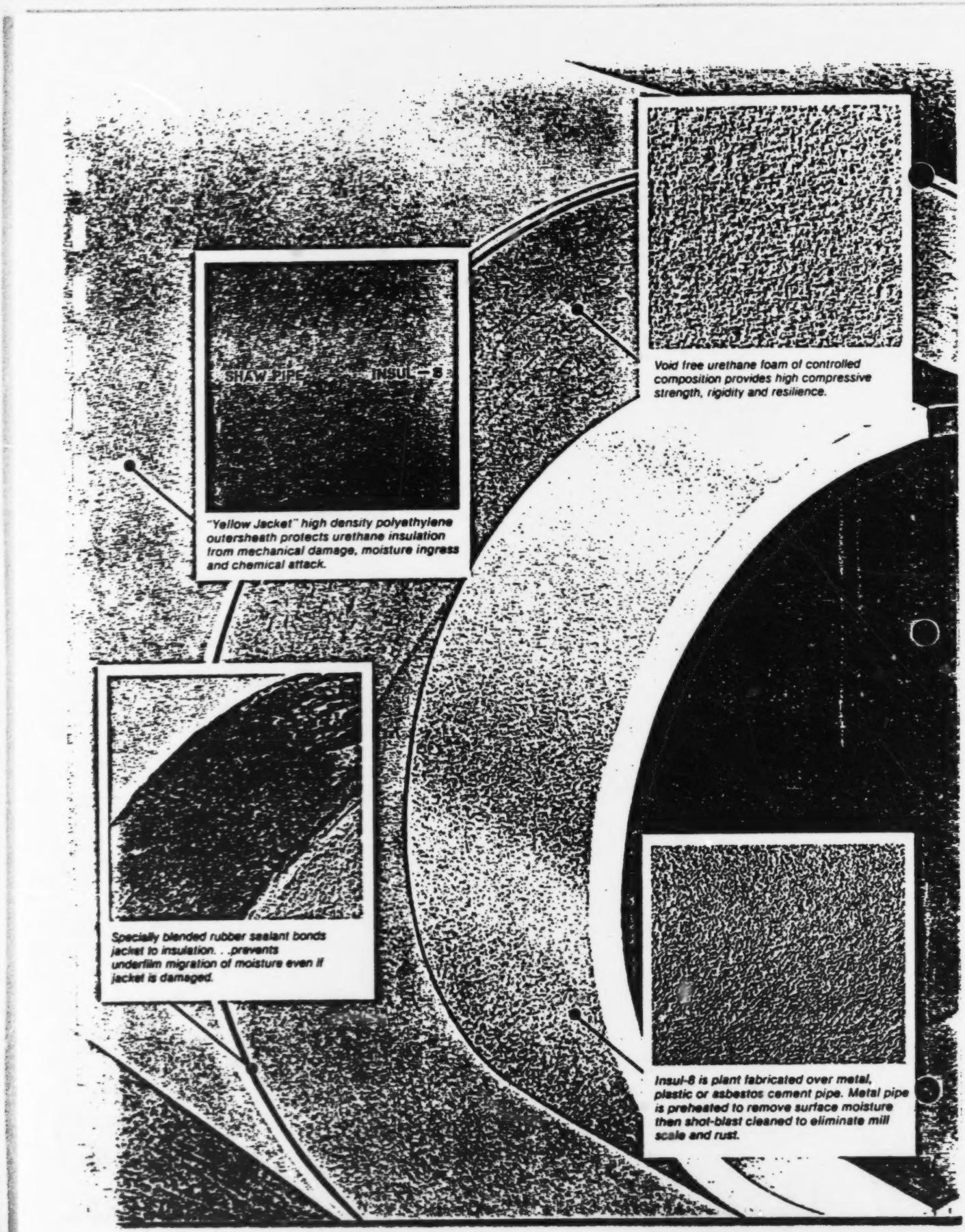
Shaw Pipe Information

PLANT FABRICATED

insul-8®

Proven protection against freezing or heat loss in underground lines.





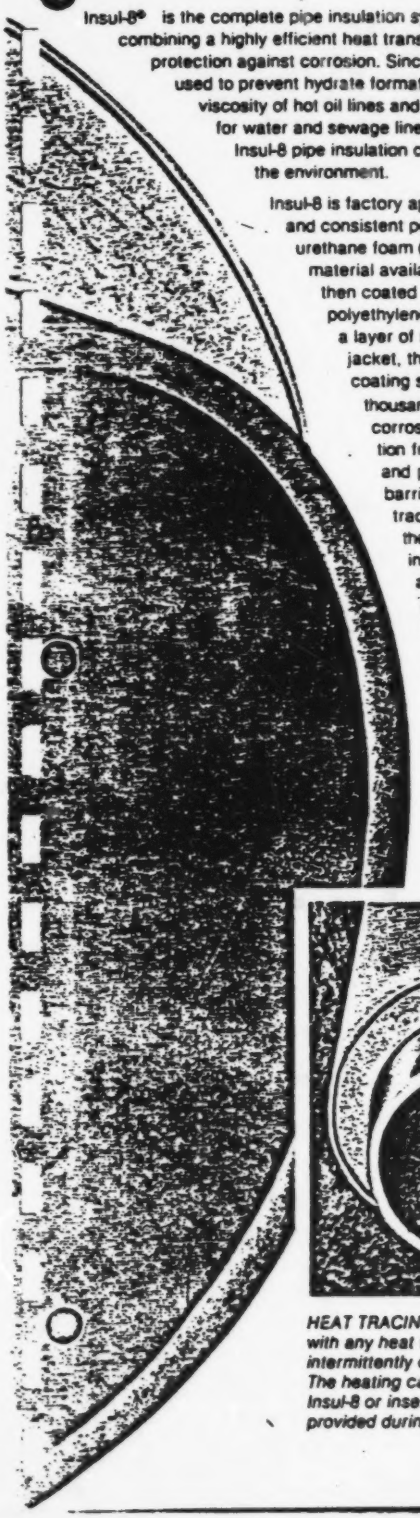
"Yellow Jacket" high density polyethylene outersheath protects urethane insulation from mechanical damage, moisture ingress and chemical attack.

Void free urethane foam of controlled composition provides high compressive strength, rigidity and resilience.

Specially blended rubber sealant bonds jacket to insulation. . .prevents underfilm migration of moisture even if jacket is damaged.

Insul-8 is plant fabricated over metal, plastic or asbestos cement pipe. Metal pipe is preheated to remove surface moisture then shot-blast cleaned to eliminate mill scale and rust.

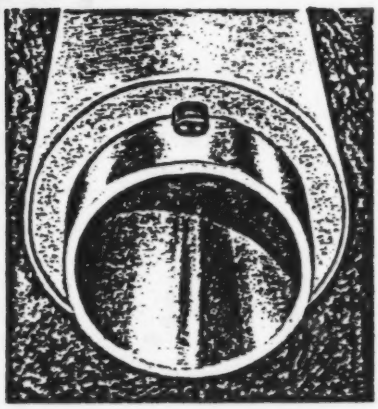
Meet your specific thermal requirements economically. . . protect the environment and ecology. . .with Shaw Insul-8.•



Insul-8• is the complete pipe insulation system for buried pipelines, combining a highly efficient heat transfer barrier with exceptional protection against corrosion. Since 1966, Insul-8 has been used to prevent hydrate formation in gas pipelines, maintain viscosity of hot oil lines and provided freeze protection for water and sewage lines. By reducing heat loss, Insul-8 pipe insulation conserves energy and protects the environment.

Insul-8 is factory applied to ensure high quality and consistent performance. At the plant, polyurethane foam (the most efficient insulation material available) is applied to the pipe, then coated with a seamless, high density polyethylene jacket extruded directly over a layer of sealant. This protective jacket, the same Yellow Jacket• coating system that is protecting thousands of miles of pipe from corrosion, protects the insulation from mechanical damage and provides a moisture-tight barrier. Channels for heat tracing can be installed at the factory and pre-moulded insulation modules for joints and fittings are provided. Field-applied Canusa• heat shrink sleeves are supplied to maintain the integrity of the jacket at all joints. Insul-8 can be applied to all types of steel, cast iron, plastic or asbestos cement pipe.

For assistance in designing insulation systems to meet the specific thermal and engineering requirements of each job, contact Shaw Pipe Protection.



HEAT TRACING — Insul-8 is compatible with any heat tracing method to protect intermittently operated lines from freezing. The heating cable can be an integral part of Insul-8 or inserted later through a channel provided during manufacture.

THE INSULATION

Insul-8 uses rigid polyurethane foam, a material combining exceptional insulating properties with high mechanical strength, high resiliency and high closed cell content.

The mechanical strength and resilience result in a self-supporting system, allowing Insul-8 to be safely shipped by truck, train, or ship. The high closed cell content results in a very low moisture permeability and ensures retention of the foam's insulating properties.

Unlike most other pipe insulations, the polyurethane foam is bonded directly to the surface of the pipe during the application procedure, thus creating a barrier against corrosion while enhancing the mechanical properties of the system.

THE JACKET

Yellow Jacket• , consisting of an undercoat of sealant and a sheath of high density polyethylene, is used to protect the Insul-8 system. The seamless polyethylene jacket is highly resistant to moisture, acting as a continuous vapour barrier, and its tough physical characteristics protect the insulation from mechanical damage and abrasion. The sealant, a non-drying resilient rubber based compound, bonds the jacket to the insulation and thus prevents underfilm migration of moisture.

JOINT FINISHING AND FITTINGS

In the field, joints, elbows and tees are fitted with pre-moulded insulation modules provided by Shaw Pipe Protection. Each joint is completed with Canusa • heat shrink sleeves or heat shrinkable tapes which maintain the integrity of the jacket and provide complete moisture protection.

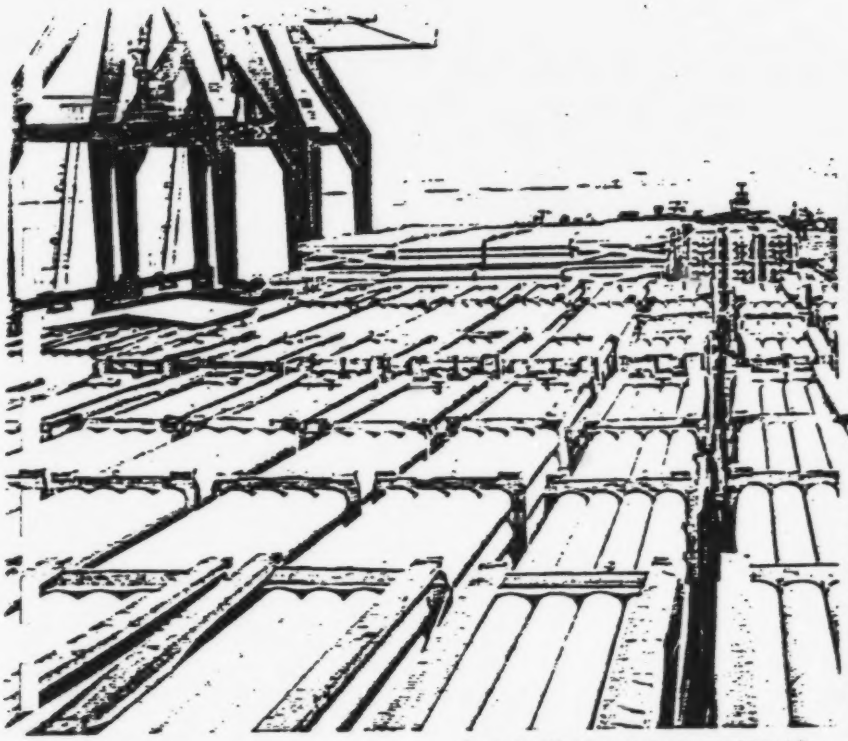
FIELD HANDLING AND INSTALLATION

Insul-8 is supplied ready for immediate installation. The system can be hauled, stockpiled, strung, lowered-in, and back-filled using conventional pipeline methods, although some minor modifications in handling and bending equipment are generally required. Specific details of handling procedures are available from Shaw Pipe Protection.

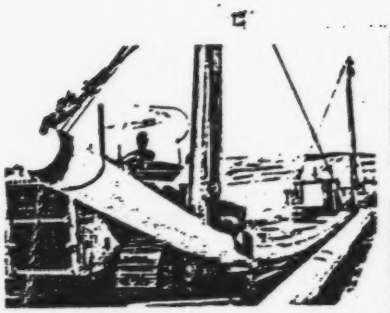
TECHNICAL SERVICE

Shaw Pipe Protection can provide technical assistance to the customer in all aspects of insulation design and installation. For applications which fall outside the standard product line, custom designs can be supplied. For high temperature lines, Shaw Pipe Protection can supply advanced polymeric foam formulations to meet each customer's individual requirements.

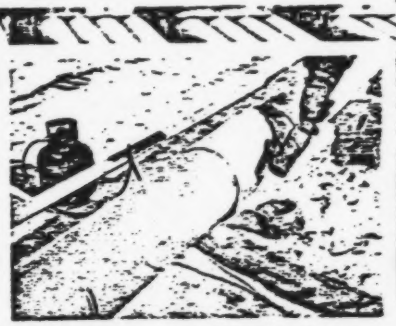
• *Insul-8, Yellow Jacket and Canusa are registered Trade Marks of Shaw Pipe Industries Ltd., Shaw Pipe Protection registered user.*
**Insul-8 — Patented 1967.*



Part of a 25 mile consignment of Insul-8 awaits shipment to Indonesia. Four-inch line is being used to move hot oil.



FIELD BENDING — For field bending, use padded bending shoes and normal pipelining methods.



FIELD JOINTS — Pre-moulded urethane halves are provided for welded joints and fittings. Canusa Heat Shrink Sleeves ensure moisture-proof field joints.

PLANT FABRICATED **insul-8**

Technical Data

DIMENSIONS

Outside Insulation Diameter:	5 in. to 24 in.
Insulation Thickness (nominal):	1 in. to 4 in.
Pipe Lengths:	up to 64 feet

(Dimensions not listed in the standard sizes above can be made available as custom orders)

MATERIALS

POLYURETHANE FOAM:

Typical Properties

- density (lbs./cu. ft.)	2.5
- compressive strength (psi)	30
- initial K-Factor (BTU-in/Ft² - hr - °F)	0.13
- water absorption (gms/cc)	0.016
- water vapour transmission (perm-inch)	2
- closed cell content (%)	90 min.
- service temperature range (°F)	-300 to + 200
(°C)	-185 to + 95

Custom Design

The following properties can be varied to meet design requirements:

- density (lbs/cu. ft.)	2.5 to 6
- compressive strength (psi)	20 to 90

Also available using ISOCYANURATE FOAM for application temperatures from 200 to 325°F (95 to 160°C.)

YELLOW JACKET® SHEATH:

Sealant thickness (mils)	10 nominal
Jacket thickness (mils)	45 nominal
Tensile Strength (psi)	3500
Elongation (%)	400
Water vapour transmission (gms/day through 100 sq. in. sheet, 20 mils thick)	0.0001

SHAW
PIPE PROTECTION GROUP

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Telex 038-21734

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Rexdale, Ontario M9W 1M7
(416) 743-7111
Telex 069-89435

Shaw Pipe Protection Limited
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Hamilton, Ontario L0R 1P0
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Telex 058-25898

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West Dapto Road, Wollongong
New South Wales, Australia 2526
042 613455
Telex 29123

LITHOGRAPHED IN CANADA

APPENDIX F

Heat Meter Information

WOLLASTON-SCHOOL ONLY-8 MONTH HEATING

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-202039.
PUMP COS	13.0	7.8	-25816.
HEAT LOSS	13.0	7.8	0.
MAINT	13.0	7.8	-68336.
HEAT SALES	13.0	7.8	531503.

TOTAL PRESENT WORTH OF PROJECT =$ 235312.

WOLLASTON-SCHOOL ONLY-BASE DATA-INFLATION = FUEL ESCALATION

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-202039.
PUMP COS	13.0	7.8	-19742.
HEAT LOSS	13.0	7.8	0.
MAINT	13.0	7 8	-68336.
HEAT SALES	13.0	7.8	455574.

TOTAL PRESENT WORTH OF PROJECT =$ 165457.

WOLLASTON -ALL FACILITIES- BASE-INFLATION=FUEL ESCALATION

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-320074.
PUMP COS	13.0	7.8	-75929.
HEAT LOSS	13.0	7.8	0.
MAINT	13.0	7.8	-106301.
HEAT SALES	13.0	7.8	830350.

TOTAL PRESENT WORTH OF PROJECT =$ 328047.

WOLLASTON-ALL FACILITIES-INFLATION=FUEL ESCALATION-8 MONTH HEATING

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-320074.
PUMP COS	13.0	7.8	-101745.
HEAT LOSS	13.0	7.8	0.
MAINT	13.0	7.8	-106301.
HEAT SALES	13.0	7.8	982208.

TOTAL PRESENT WORTH OF PROJECT =$ 454089.

Valmet

The total system for heat energy measurement developed by Valmet consists of heat meters, water meters and analyzers for maintenance and calibration as well as process analyzers, all made by the same manufacturer. The Valmet system suits all measuring purposes.

...The Right Choice.

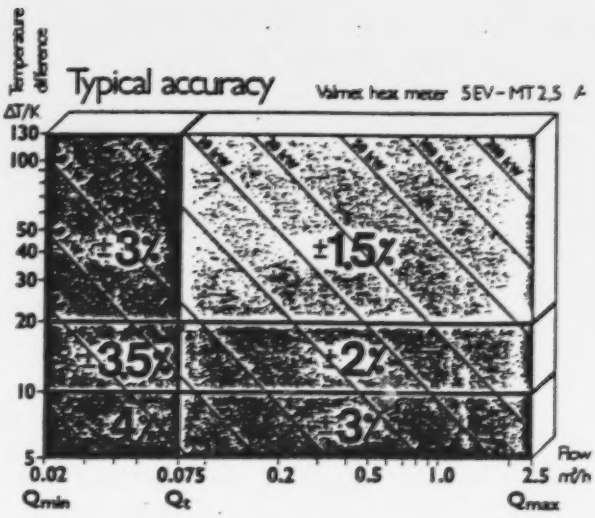
The system for heat energy measurement will be of great advantage to the users. Products, all made by the same manufacturer, guarantee the total accuracy of the measurement. Materials of high quality and reliable construction ensure the long service life of the equipment. These facts increase the measuring economy. As an example of the Valmet solution, we offer a battery operated heat meter planned for small-scale consumers. Wide measuring range enables measurement both in summer and in winter. Long-lasting batteries guarantee continuous measurement regardless of A.C. interruptions. Stable temperature detectors feel the real process temperature.

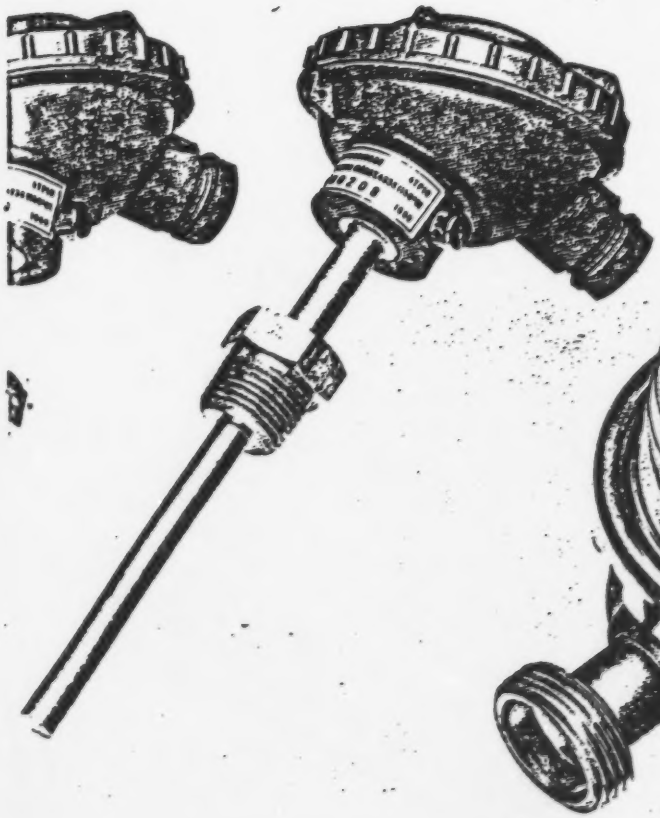
The multi-jet construction of water meters guarantees that the accuracy and sensibility is maintained even with small flows. Impurities in the water are repelled since the measuring machinery is made of special plastics, in addition

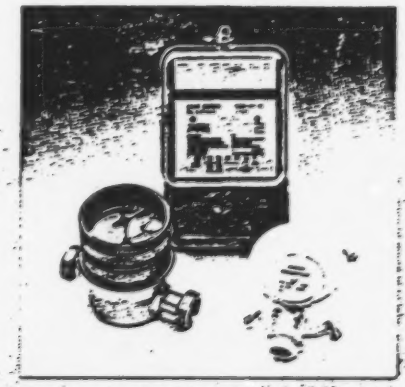
Choice...

to which the body is constructed of acid resistant steel; both of these factors enable the meters to withstand high temperatures, and the service life of the meters is extended.

Detailed information on Valmet heat energy equipment is to be found on our technical information sheets. Valmet is prepared to solve your measuring problems economically.

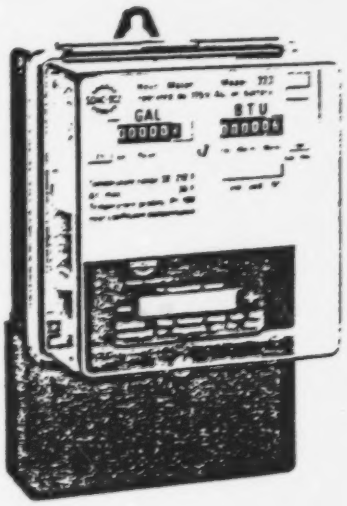






Thermal Energy Metering Systems

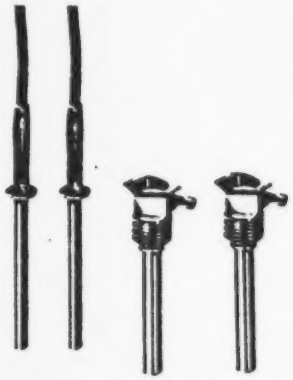
Provides Precise Energy And Flow Measurement In Cold, Hot Or Chilled Water And Solar Systems



System Components

1. Electronic Integrator Model 323

- Interchangeable modules for battery (min. 5 yr. life) or 115V AC operation
- Readout in U.S. BTU & Gal. or S.I. units
- Heat Coefficient automatically compensated for water (or other liquids on request)
- Accessory remote display unit
- Accessory LED delta-t display on 115V unit
- Provision for security seal
- Flow signal LED, 1 flash per volume pulse



2. Temperature Sensors

- Platinum Pt 100 according to DIN 43760, paired for accuracy
- With 2 wire or special 4 wire 6 ft. cable
- With pair standard wells ½" NPT
- Optional surface mount sensors available
- Provisions for security seal

3. Water Meter

- Single jet, multiple jet & turbine types
- Sizes from ½" to 12"
- Dry dial, magnetic coupling
- With 6 ft. pulsar cable
- Magnetic shield
- Various construction rating combinations from 105°F to 400°F & 140 to 910 PSI
- Security sealed
- Optional pulse transmitter head only, for use with existing meters

APPENDIX G

Literature Search from the Building Services Research and Information Association, Bracknell, England

Pathname: <SYS>LOUNGE>AESL.REG
File last modified: 84-08-16.11:29:56.Thu

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WATCH THIS SPACE-SOME RCV19 MANUALS WITH TG--MORE ON ORDER

1.

£ABNO (8200537) Light current systems and applications for industry
AUTHOR Anon
SOURCE Elect.Rev. 12th February 1982. vol.210. no.6. 28-35.
ABSTRACT The special section in this issue highlights some topical electronic applications from European companies. 'Solid state technology for developing countries'. Describes MTE Ltd England solid state modules known as SSRs. 'Micros and ultrasonics for chp heat metering'. A description of a Danfoss England ultrasonic flowmeter. 'Electronic boiler drum water level measurment'. An electronic system call Hydrastep, manufactured by Solartron Electronic Group England is described. 'Computed based control for effluent plant'. The advantages of the system and a block diagram are given. provided by Kennedy and Donkin Ltd. 'Tank fuel levels by telephone'. Kent Measuring Instruments England. System is described. 'Inductive proximity switches'. The advantages of those produced by Metzmuhr and Jung GmbH of the German Federal Republic are given. 'Catching transients'. A transient recorder for interference and other rapid events in the system, made by Wandel and Goltermann, German Federal Republic, is described. 'Energy saving French micro'. A description of the microcomputer already in service controlling load is given. Manufacturers are Clemessy. Mulhouse. France. 'Industrial programmable controller'. Designed to give automatic control of machines using up to 8 outputs, made by Clevestorm Ltd England. Maximum demand controller. Description of unit made by GEC Measurements England. 'Uninterruptible powrr supply'. A range of units made by Gould Deltec Wales is described. 'Motor driver'. A three chip motor driver for small dc motors available from B.A. Electronics of Bristol. Made in Italy. 'Heating controller'. A central heating and air conditioning controller is described. Made in England by Sensors and Systems Ltd.
SOURCE £LANG E
KEYWORDS District_heating, heat_meters, combined_heat_and_power_generation, controls. computers. switches, UK. Germany. microcomputers. ETN (Hydrastep)

2.

£ABNO (8101419) Reviewing the position of c.h.p. in the UK
AUTHOR Fells:I.
SOURCE Bldg.Serv.Environ.Engr. August 1981. vol.3. no.12, 10-11, 4 figs.
ABSTRACT Examines prospects in the UK for combined_heat_and_power_generation for industrial, commercial and domestic applications.
SOURCE £LANG E
KEYWORDS Factories. heat_meters. district_heating, economics, cost, energy_conservation
CIBDOC Heating : Electrical

3.

£ABNO (8101788) Field performance of evaporative heat metering in district_heating schemes
AUTHOR Fisk:D:J. Eastwell:A:S.
SOURCE Department of the Environment, Building Research Establishment. H.M.S.O. 1981. 12 figs, 8 tabs, 25pp price 2.00 pounds.
ABSTRACT States the the evaporative radiator heat meter is the most commonly used in district heating schemes in the UK. Describes trials which are the first ever undertaken in which this metering principle is compared with other methods of apportioning heat directly in field conditions. The trials were conducted from November 1977 to December 1978 and from October 1979 to September 1980. Some 40 dwellings were surveyed on two sites, A and B. A pair of integrating heat meters calibrated at the Building Services Research and Information Association were installed in each dwelling. at site A measuring heat consumed for space_heating and at site B measuring the total heat consumed for space heating and domestic hot water. Describes in detail the sites. experimental precautions taken and results obtained and the statistical principles employed in the analysis. Intends the report to form a basis upon which to assess the resource implications of alternative methods of cost allocation. Identifies a number of maintenance factors which could relate to evaporative heat meter performance.
SOURCE £LANG E
KEYWORDS Heat_meters. radiators. testing. experiment. comparing. housing. domestic hot_water_installation. costs. statistics

£ABNO (8201831) Combined heat and power

AUTHOR Ashley:S. et al

SOURCE J.Chart.Inst.Bldg.Serv. October 1982, vol.4. no.10, 33-39. 1: figs.

ABSTRACT Provides four short articles treating aspects of combined heat and power generation for district heating in the UK. - the Atkins report on chp/dh, the practicalities, effective metering and balancing chp systems.

SOURCE £LANG E

KEYWORDS Combined_heat_and_power_generation, district_heating, UK. feasibility, heat_meters, regulating

3.

£ABNO (8400363) Heat supply - the UK dilemma

AUTHOR Chartered Institution of Building Services

SOURCE *DT (CIBS Symposium) London. 22nd February 1984. 62pp.: 8697.1.

ABSTRACT Presents the text of the six papers given at the symposium - Effective heating technology using off peak electricity, Ackery:D:W., Combined heat and power, Orchard:W:R:H., Heat meters and associated legislation, Brierly:A., The philosophy of the bivalent system, Morris:D., Trends in heating, Eastwell:A:E. The metering of domestic heat loads and the development of systems for the market Anon.

SOURCE £LANG E

KEYWORDS £PUBDATE (22/02/84) £DC (C)
UK, off_peak_electricity, combined_heat_and_power, heating, heat_meters. legislation. heat_load, heat_pumps. district_heating, tariffs, housing

1.

£ABNO 7900093 Domestic hot water- its significance as an energy problem
L'eau chaude sanitaire. Importance energetique du probleme

AUTHOR Quinton:J.

SOURCE *DT (Chaud.Froid.Plomb.) October 1978. vol.54. no.10. 5-11. 10 figs. 1 tab. (in French)

ABSTRACT Provides results of a study of monthly domestic hot water draw-offs in France in dwellings supplied by district heating and individual boilers. Determines average consumption for a sample of 25 000 local authority dwellings, for an apartment building and for an individual flat equipped with a heat meter. Notes reduction of 20-30% with installation of heat meters. Examines causes of variable consumption. Summarises results in tables and histograms. Treats efficiency of hot water production in winter and summer. Evaluates annual hot water consumption for France. Treats significance of findings for manufacturers of solar domestic hot water installations.

KEYWORDS £PUBDATE (00/10/78) £DC (J)
domestic, hot_water_supply, France, district_heating, boilers. domestic, water_heaters, performance, comparing, efficiency, heat_meters

2.

£ABNO 7900093 Domestic hot water- its significance as an energy problem
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KEYWORDS £PUBDATE (00/10/78) £DC (J)
domestic, hot_water_supply, France, district_heating, boilers. domestic, water_heaters, performance, comparing, efficiency, heat_meters

3.

£ABNO (8200406) Consequences of heating costs and new building rents on heat supply and heat billing according to £RS (DIN 4713). 4714
/[Auswirkungen der Heizkosten V und der Neubaumieten V auf die Warmelieferung und Warmeabrechnung unter Berucksichtigung der DIN 4713 and 4714]

AUTHOR Pollmeier:H.
SOURCE Fern.Internat. February 1982. vol.11. no.1. 15-18. 4 refs.
ABSTRACT Explains that only those concerns are not subject to the requirements of Section 18 of the District Heat Regulations (AVB Fernwarme), paragraphs 20 to 23a, which invoice heating costs exclusively to the building owner. In the future they will merely be required to use metering devices which comply with the legislation for measuring standards. However, district heat suppliers are affected if they have direct billing agreements with tenants or have a central contract with the owner to collect from individual tenants. For these suppliers it is important to observe that heating costs are billed according to consumption. If this achieves the desired savings in primary energy or if the heat energy costs are more fairly distributed remains to be seen.
SOURCE £LANG G
KEYWORDS District_heating. legislation, Germany. energy_conservation. housing. heat_meters. energy_consumption, £RS (DIN 4714)

4.

£ABNO (8200556) What has been the effect of compulsory calibration on the properties of the heat meters coming on to the market and what developments can be perceived?
/[Wie hat sich die Eichpflicht auf die Eigenschaften der auf den Markt kommenden Warmezahler ausgewirkt und welche Entwicklungen sind erkennbar?]

AUTHOR Lutz:H.
SOURCE Fern.Internat. February 1982. vol.11. no.1, 8-10. 6 figs. 1 tab. 7 refs.
ABSTRACT The compulsory calibration of heat_meters as expected has not led directly to improved heat meters. But it has increased the number of those who think about improved heat meters and testing apparatus. This, together with new technologies. has already led to improved heat measuring and testing devices. This trend is still recognisable since there is an urgent need for tested apparatus.
SOURCE £LANG G
KEYWORDS District_heating. Germany, legislation, calibrating, accuracy

5.

£ABNO (8200557) Electronic heating charge allocation system
/[Elektronisches Heizungskostenverteilungssystem]

AUTHOR Anon
SOURCE Heiz.Luft.Haustech. January 1982. vol.33, no.1. 14.
ABSTRACT Notes briefly that AEG Telefunken has developed an electronic heating charge allocation system which measures electronically the heat consumption in a dwelling and which can also measure the amount of heat given to neighbouring buildings through the walls. The system requires no maintenance and has a working life of more than 20 years. The basis of the method is to measure the difference between the radiator surface and the room temperature, with measuring elements directly on the radiator surface and on an internal wall.
SOURCE £LANG G
KEYWORDS District_heating. heat_meters. Germany. energy_consumption, housing. measuring

6.

£ABNO (8101213) The concern of the manager
/[L'inquietude du gestionnaire]

AUTHOR Voillot:L.
SOURCE Chauff.Vent.Condit. April 1981. vol.57, no.4. 11-19. 6 figs.
ABSTRACT Discusses French legislation stipulating the introduction of heat metering and the allocation of heating charges according to individual consumption in multi-family housing with communal heating systems. Points out that although this type of system will certainly lead to energy savings, it is possiblethat there will be anomalies, particularly in buildings of the prewar and immediate post war periods, where the heating systems are comparatively primitive and inefficient with on-off control and where attemps to conserve energy may load to deterioration of the building fabric or to people living below comfort levels. Notes extra charges caused by the introduction of heat meters. Notes the need to ensure in every case that cost savings exceed additional costs. Notes further problems with relatively exposed corner apartments which require more heat to maintain a normal temperature and heat leaking from heated to unheated apartments. Concludes by giving detailed, illustrated examples of various methods of heat metering in communal heating schemes for existing and new buildings.
SOURCE £LANG F
KEYWORDS France, heat_meters. charging, flats. housing. energy_consumption, district_heating, energy_conservation. thermal_comfort, heating_installations. cost
CIBDOC Heating : Measuring instrument

7.

£ABNO (8101214) The R.C.C. system for the allocation of heating charges
/[Le systeme R.C.C. - un repartiteur des charges de chauffage]

AUTHOR Pelce:P.
SOURCE Chauff.Vent.Condit. April 1981, vol.57, no.4, 21-23, 7 figs.
ABSTRACT Illustrates schematically and photographicaly and describes the operation of the RCC system, which integrates the systems of heat metering and heating charge allocation into a single operation. The system is based on the metrostatic principle which comprises a thermostatic valve on a radiator with a handwheel in its head equipped with a variable resistance directly proportional to the set temperature and transmitted by two wires to the meter outside the aprartment, which analyses the signals from up to a dozen thermostatic radiator valves and displays the charge accumulated to date. States the system conforms the requiremrnts of recent French energy_conservation legislation. The system is currently being tested in numerous locations in Germany and France.
SOURCE £LANG F
KEYWORDS Charging, heat_meters, France, thermostatic_valves, radiators, district_heating, heating, costs, testing, housing, flats, energy_consumption
CIBDOC Measuring instrument : Heating

8.

£ABNO (8101215) The rational use of heat meters
/[Utilisation rationnelle des compteurs d'energie thermique]

AUTHOR Roy:D.
SOURCE Chauff.Vent.Condit. April 1981, vol.57, no.4, 31-33, 11 figs, 5 tabs.
ABSTRACT Discusses generally problems associated with electronic heat metering. Treats measurement errors over a heating_season for systems with constant and variable flow rates.
SOURCE £LANG F
KEYWORDS France, heat_meters, charging, energy_consumption, flats, housing, district_heating, cost, accuracy
CIBDOC Heating : Measuring instrument

9.

£ABNO (8101217) The GERTEP system - a heating charge allocator
/[Le systeme Gertep - un repartiteur des frais de chauffage]

AUTHOR Quinton:M.J.
SOURCE Chauff.Vent.Condit. April 1981, vol.57, no.4, 25-30, 8 figs, 1 tab.
ABSTRACT Describes a heat metering system which permits charges to be read off outside the apartment concerned, which can be installed in most types of heating installation and which is simple to operate. Describes its operating principles in some detail. Illustrates the system in diagrams and photgraphs. Describes actual example of its application to an old apartment building containing six flats. Treats system maintenance, installation and startup.
SOURCE £LANG F
KEYWORDS Heat_meters, France, flats, housing, charging, costs, district_heating, cost, energy_consumption, £TN (Gertep)
CIBDOC Measuring instrument : Heating

10.

£ABNO (8200205) 13 Heat_meters for hot water and low temperature hot water installations
/[Warmezahler fur Warm- und Heisswasserheizungen]

AUTHOR Anon
SOURCE TAB. October 1981, no.10, 831-834, 7 figs, 2 tabs.
ABSTRACT Describes some makes of heat meters available on the West German market. Provides details of their operation and technical design principles.
SOURCE £LANG G
KEYWORDS Germany, heat_flow, metering, radiators, space_heating, district_heating, hot_water_installations

11.

£ABNO (8201059) Research in plumbing, heating and construction
/[Forschung in der Sanitar-, Heizungs- und Bautechnik]

AUTHOR Anon
SOURCE Sanit.Heiz.Tech. April 1982, vol.47, no.4, 275-277.
ABSTRACT Provides brief summaries of research by publicly funded bodies in West Germany in the field of building services - corrosion in galvanised steel pipes for drinking water supply, plastics piping in floor heating systems, heat demand and non-steady heating, low energy houses, heat pumps in dwellings with an existing boiler, earth source heat pumps for schools and sports centres in Ajoelby, application of solar energy in district heating systems, solar energy, heat meters, solar collectors, space requirements of shower cubicles, reducing noise in water piping, interaction of the built environment and heat supply systems, atmospheric pollution by domestic chimneys and the effect of wind.
SOURCE £LANG G
KEYWORDS Research, corrosion, pipes, potable_water, plastics, floor_heating, housing, heat_pumps, schools, sports_centres, solar_energy, district_heating, heat_meters, solar_collectors, shower_cabinets, air_pollution, intermittent_heating

12.

£ABNO (8201624) Evaporative heat meters are becoming electronic /['Verdunster' werden elektronisch]

AUTHOR Genath:D.
SOURCE Sanit.Heiz.Tech. June 1982, vol.47, no.6, 428-431. 5 figs.
ABSTRACT Notes regulations in West Germany requiring the installation of heat meters in classes of accommodation to ensure individual charging for heat consumed with the attendant energy savings. Notes the wide application of evaporative heat meters for this purpose. Briefly describes their operating principles and the fact that they are only suited to supply water at temperatures above 60&0oC. Discusses the appearance on the market of electronic heat meters whose application is similar to evaporative heat meters. Treats the three main competing systems and their operating principles.
SOURCE £LANG G
KEYWORDS Heat_meters, cost, housing, charging, district_heating

13.

£ABNO (8201838) Heat metering and allocation of heating charges /[Comptage de chaleur et repartition des frais de chauffage]

AUTHOR Voillot:L.
SOURCE Chaud.Froid.Plomb. October 1982, vol.36, no.430, 79-83. 4 figs.
ABSTRACT Part one of a series of articles. Discusses recent French legislation concerning heat metering and the allocation of heating charges, its development as far as the publication of the first texts and difficulties associated with its introduction into existing routines and systems. Examines the different systems of heat metering and charge allocation for various applications.
SOURCE £LANG F
KEYWORDS District_heating, housing, France, heat_meters

14.

£ABNO (8301463) International District Heating address book and supplier directory 2nd Edition 1983 /[Fernwarme International Adressbuch und Bezugsquellenverzeichnis 2. Ausgabe 1983]

AUTHOR Anon
SOURCE Fern.Internat. 1983, 295pp, figs, tabs. 697.34.
ABSTRACT Gives the names, addresses and ranges of suppliers of technical district heating products and services plus a company directory of the international district heating industry, lists of addresses of Unichal and national district heating organisations, a Unichal membership directory, a national membership directory plus a supplement listing heat meters and heat charges approved for use in West Germany. In addition supplies the text in French, German and English of the general reports presented at the Unichal Congress 1983 in Lahti, Finland. Titles are - District heating supply systems in West European countries. Neuffer:H., Heat transport over a long distances. House service connections for hot water supply. Study of sensitivity. Energy pricing and energy tariffs. Research and development projects in district heating in the Unichal area. District heating statistics 1981. The heat pump as a heat station.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/00/83) £DC (B) District_heating, tariffs, statistics, directories, heat_meters, heat_pumps, reference_books

15.

£ABNO (8301578) Electronic heat meters - a survey /[Elektronische Heizkostenverteiler - Eine Ubersicht]

AUTHOR Goettling:D:R.
SOURCE KDT (Heiz.Luft.Haustech.) May 1983, vol.34, no.5, 205-210, 9 figs, 2 tabs, 2 refs.
ABSTRACT Provides a detailed review of the different makes of electronic heat meters available in West Germany. Treats their fields of application and operating principles.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/05/83) £DC (J) Heat_meters, electronic+heat_meters, Germany, district_heating

16.

£ABNO (8300538) State-recognised testing station for heat metering instruments at the Bewag (Berlin Power and Light Company) /[Staatlich anerkannte Prufstelle fur Warmemengenmessgerate bei der Bewag]

AUTHOR Hoffmann:S., Junge:H:J.
SOURCE Fern.Internat. 1982, vol.11, no.6, 409-413, 6 figs, 1 tab, 4 refs.
ABSTRACT Describes the state-recognised heat meter testing station, in operation in West Berlin since March 1981. Treats the testing programme for hot water meters up to 95&0oC and 70 m&3/h nominal loads temperature sensors (40 to 120&0oC) and cold water meters up to 10 m&3/h. Discusses the testing station concept and test procedures for hot water and cold water meters. Inductive comparative meters have been selected with both analogue and impulse outlets.
SOURCE £LANG G
KEYWORDS Testing, district_heating, heat_meters, Germany

17.

£ACNO (8300910) Advantages and problems of electronic heat meters
/[Vorzuge und Probleme elektronischer Heizkostenverteiler]
AUTHOR Zieglerill.
SOURCE Heiz.Luft.Haustech. February 1983, vol.34, no.2, 54-60. 4 figs, 12 refs.
ABSTRACT States that the deadline in West Germany for the general introduction of heat billing on the basis of individual consumption (30 June 1984), requires a comparison of the different types of electronic systems and between electronic and evaporative types. Lists a large number of evaluation criteria. In addition to some principal faults of the various systems that have already been discussed, notes psychological factors, and the need to ensure against tampering.
SOURCE £LANG G
KEYWORDS Heat_meters, Germany, district_heating, comparing, evaporative_heat_meters, electronic+heat_meters

1.

£ABNO (8100528) The Clorius heat metering system
/[Het £TW (Clorius) warmtekostenverdeelsysteem]
AUTHOR Kat:J:D.
SOURCE Verwarm. Vent. December 1980, vol.37, no.12, 787-792. 2 figs.
ABSTRACT Recalls history of the evaporative heat meter for collective heating installations as constructed by the Danc Odin Clorius 1930 and introduced into the Netherlands after 1953. Details technical, organizing and adminstrative aspects of the system as developed by Warmtemeter B.V. at Schiedam such as contracting, registration, installation, computation, and accounts.
SOURCE £LANG (In Dutch)
KEYWORDS Heat_meters, district_heating, charging
CIBDOC Measuring instrument : Heating

2.

£ABNO (8100529) Operation and measuring accuracy of evaporation meters
/[De werking en de meetnauwkeurigheid van verdapingsmeters]
AUTHOR Van der Vecht:D:J.
SOURCE Klimaatbeheersing. December 1980, vol.9, no.12, 653-658, 675. 11 figs, 4 tabs, 9 refs.
ABSTRACT Describes system of evaporative heat meter fixed to radiator. Recalls researches on system accuracy and administration by Mansa:J:L. (1947 and 1951 and Nipkow:J. (1977. Surveys results of TNO report 'Heat Measurement in Dwellings'. Part 1 'Evaporation meters', 1979. Treats theoretical study on evaporation and scale graduation. Calculates measuring fault percentages on behalf of a detailed simulation. Studies effects of various fraudulent attempts at metering deflection. Treats influences of solar_radiation upon the meter, vertical conduit pipes nearby and heat flows from and to the neighbours.
SOURCE £LANG (In Dutch)
KEYWORDS Heat_flow, district_heating, Netherlands, heat_meters
CIBDOC Measuring instrument : Heating

3.

£ABNO (8100903) Heat consumption determination in homes using heat meters
/[Meting van warmtegebruik in woningen met behulp van warmtedoorstroommeters]
AUTHOR Brand:R:A.
SOURCE Verwarm.Vent. March 1981, vol.38, no.3, 291-298, 11 figs, 5 refs.
ABSTRACT Reports researches into the expected performance and accuracy of individual heat consumption metering with heat meters, made by order of the Dutch Ministry of Housing NVRO as a sequel to research with evaporative heat meters. Separately treats the accuracy of both electrical and mechanical heat meters depending on system temperature variation and the meter accuracy over a whole heating season. Also published in Klimaatbeh, March 1981, vol.10, no.3, 136-140.
SOURCE £LANG (in Dutch)
KEYWORDS District_heating, heat_meters, energy_consumption, dwellings, Netherlands, heating_season
CIBDOC Measuring instrument : Heating

4.

£ABNO (8101216) Heat measurements with a maintenance-free flowmeter
/[Warmtemeting met een onderhoudsvrije debietmeter]
AUTHOR Geluse:R:H:J.
SOURCE Klimaatbeh. March 1981, vol.10, no.3, 141-146. 10 figs.
ABSTRACT Treats heat meter designed by the KEMA inspection office for electrotechnical materials at Arnhem, for the use of small consumers of district heat. Explains working principle, a tube in which a turbulent flow is heated by a given quantity of heat. The temperature increase of the liquid flowing through it is inversely proportional to the mass-flow per unit of time. The required heat is derived from the temperature difference available. Describes prototype and tests carried out especially on the effect of the boundary layer in the tube at low velocities. A cooperation agreement has been made with a Dutch manufacturer for further development and production.
SOURCE £LANG (in Dutch)
KEYWORDS District_heating, Netherlands, heat_meters, heat_exchangers, boundary_layers, measuring
CIBDOC Measuring instrument

5.

£ABNO (8101546) Electronic measuring system for heating cost allocation
/[Elektronisch meetsysteem voor stookkostenverdeling]

AUTHOR Anon
SOURCE Verw.Vent. June 1981. vol.33, no.6. 544-553. 9 figs.
ABSTRACT Treats £TN (Heikozent) measuring system for individual consumption-dependent distribution of central heating costs as developed by AEG-Telefunken. Explains the method based on the thesis that the heat emitted by a radiator is determined by radiator surface_temperature and the temperature difference of radiator surface and room air. Confirms this thesis in laboratory experiments. Demonstrates system accuracy from measurement report from two complexes of 15 houses.
SOURCE £LANG (in Dutch)
KEYWORDS District_heating, Netherlands, heat_meters, heat_flow, experiment, housing
CIBDOC Measuring instrument : Heating

6.

£ABNO (8101547) KEMA heat meter, from mechanical problems to electronic solutions
/[KEMA warmtemeter, van mechanische problemen naar elektronische oplossingen]

AUTHOR Wichern:F:H:M.
SOURCE Verw.Vent. June 1981. vol.33, no.6. 537-542, 7 figs, 1 ref.
ABSTRACT Notes need for reliable heat meters with a minimum of maintenance in planned district_heating systems. Describes the £TN (KEMA) meter which basically only senses several temperatures within the meter box, but obtains total flux reading from the relation between temperature differences along feed-in and feed-out lines and a thermal connection between those lines. Notes that meter developments show a shift from mechanical hardware problems to electronic signal processing problems. Expects computation problems to be solved electronically - economically by larger production quantities and the use of micro-electronics (chips). Prospects a development from plain Joule reading towards circuit leakage control, day/night or season charging, telemetric reading, etc.
SOURCE £LANG (in Dutch)
KEYWORDS Heat_meters, Netherlands, measuring, temperature_measuring_equipment, calculating
CIBDOC Measuring instrument : Heating

7.

£ABNO (8101968) Energy saving legislation
/[Energiebesparingswetgeving]

AUTHOR van den Berg:A:J. Besselse:H. de Maan:H:G.
SOURCE Gas. August 1981. vol.101, no.8, 403-410, 4 figs. 16 refs.
ABSTRACT Announces introduction of Energy Saving Equipment Bill. Prospects shape and contents of the new act. Marks paragraphs on the use of low_temperature heat and the built environment. Compares legislation with that in other OESO countires. Considers resulting regulations on efficiency requirements on appliances, informative labelling of products, individual heat metering and charge in collective systems.
SOURCE £LANG (in Dutch)
KEYWORDS Energy_conservation, heat_meters, district_heating, energy_supply_and_use, Netherlands, low_temperature_water_heating

1.

£ABNO 8102901 Court rejects individual heat metering
Fastighetsdomstol forkastar lagenhetsuis varmemalning

AUTHOR Branemo:J.
SOURCE VVS (Tidskrift) July-August 1981, vol.52, no.7-8, 78 and 80. (in Swedish)
ABSTRACT Swedish court has rejected evaporative heat meters as a means of charging for heat from a district heating scheme, due to their poor accuracy. The decision is important as it is now final and creates a precedent.
KEYWORDS Sweden, heat_meters, district_heating, metering, accuracy, meters, evaporative_heat_meters, performance

2.

£ABNO (8301463) International District Heating address book and supplier directory 2nd Edition 1983
/[Fernwarme International Adressbuch und Bezugsquellenverzeichnis 2. Ausgabe 1983]

AUTHOR Anon
SOURCE Fern.Internat. 1983. 295pp. figs. tabs. 697.34.
ABSTRACT Gives the names. addresses and ranges of suppliers of technical district heating products and services plus a company directory of the international district heating industry. lists of addresses of Unichal and national district heating organisations. a Unichal membership directory. a national membership directory plus a supplement listing heat meters and heat charges approved for use in West Germany. In addition supplies the text in French. German and English of the general reports presented at the Unichal Congress 1983 in Lahti. Finland. Titles are - District heating supply systems in West European countries. Neuffer:H.. Heat transport over a long distances. House service connections for hot water supply. Study of sensitivity. Energy pricing and energy tariffs. Research and development projects in district heating in the Unichal area. District heating statistics 1981. The heat pump as a heat station.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/00/83) £DC (B)
District_heating. tariffs. statistics. directories. heat_meters. heat_pumps. reference_books

3.

£ABNO (8300418) Problems when measuring individual heat consumption in dwellings
/[Asuntokohtaisen lammitysenergian mittauksen problematikka]

AUTHOR Hekkanen:M.
SOURCE LVI. 1982. vol.34. no.10. 4-7. 4 figs. 5 refs.
ABSTRACT Notes the increasing practice in Finland of monitoring individual heat consumption in blocks of flats. Treats investigations in the University of Oulu into the possibility of achieving accurate heat measurement and charge allocation. Describes test measurements in a block of flats compared with total heat consumption in similar dwellings measured by automatic electronic thermostats. Individual measurements were also taken in two lots of terraced housing in middle Finland. Concludes that individual heat meters are suited to buildings where the individual dwellings are thermally comparable. In blocks of flats where the dwellings are very different internal heat transfer should either be prevented or taken into account using more advanced measuring methods.
SOURCE £LANG Z
KEYWORDS Measuring. Finland. flats. buildings. heat_meters. energy_consumption. housing. heat_flow. district_heating

4.

£ABNO (8400248) Investigation of changes in energy consumption patterns in existing building stock

AUTHOR Larsson:C.
SOURCE Sweden. Building Research Institute. Bulletin 1983. M83.3. 38pp. price 33.00 SEK approx. NIS.
ABSTRACT Describes the various types of energy meter at present used in existing building stock for measurement of district heating. oil heating. gas heating. electric heating. domestic electricity and cold water supplies. It is intended as an aid for pupils participating in the first stage of the investigation of changes in energy consumption patterns in existing building stock. started in 1982 by the Swedish Institute for Building Research. However the report should also be of help in other investigations involving measurements made by existing energy metering equipment. The report also describes a meter. specially developed for the investigation. and intended for recording and operating time of oil burners.
SOURCE £LANG W
KEYWORDS £PUBDATE (00/00/83) £DC (R)
Oil_heating. gas_heating. electric_heating. meters. heat_meters. energy_consumption. buildings. district_heating. drinking_water_supply

1.

£ABNO 7900043 Combined heat and power - 32-413 million pounds p.a. for the heating and ventilating industry

AUTHOR Orchard:R:H.
SOURCE Heat. Vent. Rev. November 1978. vol.19. no.1. 16-17. 1 fig. (in English)
ABSTRACT The UK District Heating Association estimates value to hevac and associated industries if 10 major conurbations are converted to combined heat and power (CHP) at 32 million pounds per year for next 20 years. Estimates cost of conversion at 41 million pounds per year for next 20 years for 25% of all dwellings. Treats long-term consumer benefits. Compares relative long-term costs of heat from different systems to demonstrate cost advantages of CHP. Questions long-term future of gas industry. Denies CHP is a threat to the gas industry. Notes economic changes favouring introduction of CHP. Dismisses fears of loss of markets by competing fuel industries if CHP is introduced.
KEYWORDS combined_heat_and_power. costs. economics. district_heating. comparing. energy_supply_and_use. marketing

2.

£ABNO 7900044 Installation costs of steam plant for the combined generation of heat and power

AUTHOR Jebson:D:A.

SOURCE Elect.Rev. 27 October 1978, vol.203, no.16, 34-35. 4 figs. (in English)

ABSTRACT Describes work carried out as part of a research programme of UK Building Research Establishment to obtain cost comparison between district heating schemes supplied by combined heat and power plant and schemes supplied by conventional plant. Points out need to consider cost of both power stations using special plant for heat and power generation and of those using condensing turbines. Presents in graphs costs obtained from consultations with manufacturers of large steam turbines and studies of feasibility of heat and power generation in the UK. Derives equations which facilitate estimation of cost aspects of heat and power generation.

KEYWORDS district_heating, energy_supply_and_use, costs, comparing, combined_heat_and_power

3.

£ABNO (8301101) Planning for CHP heat

AUTHOR District Heating Association

SOURCE District Heating Association Conference. Torquay 21-23 June 1983. unpriced.* 697.34.

ABSTRACT Gives the text of the 15 papers presented at the conference - The future development of CHP and DH systems in Denmark. Mortensen:H:C.. The future development of CHP/DH systems in Finland. Rouhiainen:P.. Eerola:H.. Developing a CHP/DH system on Tyneside. Elton:L:N.. CHP/DH systems and the outlook for the inner cities. Murphy:T:F.. Computer aided planning of CHP/DH systems. Rosland:S.. Efficiency in sizing and analysing district heating networks for city CHP schemes Usher:A:G.. Rouhiainen:P.. Regional grids and heat storage systems. Scholz:F.. Operator experience of underground heat mains reliability in the UK. Birtles:A:B.. O'Sullivan:E:F.. Who Who should market CHP heat?. Murray:M:V.. Who should market CHP heat?. Hutchinson:D.. Who should market CHP heat? Healy:M.. Private sector financing of CHP/DH schemes. Cadman:M:H.. Cohen:R:L.. The potential of CHP/DH as a major energy supply option for the UK. Orchard:W:R:H.. Macadam:J:A.. The contribution to energy conservation of a national refuse incineration/recovery policy Clennul:W:A.. Lowe:D:T..

SOURCE £LANG E

KEYWORDS Denmark, Sweden, Finland, reliability, conference_proceedings, district_heating, combined_heat_and_power, UK, country, computer_aided_design, energy_storage, main_pipes, pipelines, networks, pipes, marketing, energy_conservation, refuse_incineration, heat_recovery

4.

£ABNO 8402264 Chp district heating should go ahead, says Committee

AUTHOR Anon

SOURCE *DT (Elect.Times) 22nd April 1983. no.4699. 3.

ABSTRACT The third report by the Select Committee on Energy states that steps should be taken for appropriate schemes for district heating/combined heat and power schemes to be put in hand. A summary of the report is given. The schemes at Hereford and Slough are commented upon.

SOURCE £LANG (In English)

KEYWORDS £PUBDATE (22/04/83) £DC (J)
District_heating, UK, combined_heat_and_power

5.

£ABNO 8302824 The socio-economic aspects of district heating

AUTHOR Grimes:A.

SOURCE *DT (Conference on practical aspects of district heating and combined heat and power. District Heating Association, Scottish Branch), Glasgow. 10 April 1981. 27-32. 697.34:621.31

ABSTRACT The effects of fuel poverty i.e. the dramatic increases in fuel costs since 1973 on those with low or fixed income in Scotland is discussed. These include hypothermia, and other illnesses associated with lack of proper heating, dampness, debt and disconnection. The three contributory factors to fuel poverty are prices, welfare benefits and housing. The merits of CHP from the socio-economic point of view are discussed including creation of employment, reduction of problems of hypothermia and dampness, easier payment methods and budgeting, fuel flexibility.

SOURCE £LANG E

KEYWORDS £PUBDATE (00/04/81) £DC (F)
social_problems, district_heating, combined_heat_and_power, hypothermia, UK, condensation, housing, prices, generation, costs, employment, tariffs

6.

£ABNO (8400232) Seminar on current status of CHP/DH

AUTHOR Institution of Mechanical Engineers
SOURCE *DT (Seminar on current status of CHP/DH) Steam Plant Committee. Power Industries Division, 8th November 1983, unpriced. p697.34.
ABSTRACT Presents the text of the six papers given at the seminar - Current programmes on combined heat and power, Bevan:G:G., £HP/DH - a challenge to UK industry, Anthoney:E:J., CHP/DH - a challenge to UK industry - scheme design Rowe:W:G:F., Manufacturing requirements, Cadman:A., Current status of CHP district heating, Postlethwaite:A:F., CEGB involvement, Betts:P..
SOURCE £LANG E
KEYWORDS £PUBDATE (03/11/83) £DC (C)
Combined_heat_and_power, UK, district_heating, designing, economics, electricity, conference_proceedings

7.

£ABNO (8400368) Heat supply - the UK dilemma

AUTHOR Chartered Institution of Building Services
SOURCE *DT (CIBS Symposium) London, 22nd February 1984, 62pp.* Sp697.1.
ABSTRACT Presents the text of the six papers given at the symposium - Effective heating technology using off peak electricity, Ackery:D:W., Combined heat and power, Orchard:W:R:H., Heat meters and associated legislation, Brierly:A., The philosophy of the bivalent system, Morris:D., Trends in heating, Eastwell:A:E, The metering of domestic heat loads and the development of systems for the market Anon.
SOURCE £LANG E
KEYWORDS £PUBDATE (22/02/84) £DC (C)
UK, off_peak_electricity, combined_heat_and_power, heating, heat_meters, legislation, heat_load, heat_pumps, district_heating, tariffs, housing

8.

£ABNO 8402341 Prospects for combined heat and power (CHP) in the UK - Market brief no.12.

AUTHOR National Economic Development Office
SOURCE NEDO. 1983. p697.34 (in English)
ABSTRACT This market brief outlines the state of development of combined heat and power (CHP) and district heating (DH) systems in the UK, the progress being made with studies for possible future development of CHP as an energy supply option, and the extent of manufacturing and civil engineering involvement required if that development were to take place. The brief is intended to provide an introduction for manufacturing and civil engineering firms wishing to consider whether they should become involved in current studies or in any implementation programme which may follow.
KEYWORDS £PUBDATE (00/00/83) £DC (R)
combined_heat_and_power, district_heating, UK

1.

£ABNO 7900045 Hamburg's combined heat and power system

AUTHOR Kruger:H.
SOURCE Elect.Rev. 1 December 1978, vol.203, no.21, 65-67, 5 figs, 1 tab. (in English)
ABSTRACT District heating in Hamburg has developed from 1922 to a leading system in Germany. For hot water and steam network rated demand of 1782MW(th), heat output of 1221MW(th) is currently available from 3 power stations and one refuse disposal plant. 92% of available heat is from combined heat-power generation, 82% in back-pressure stations and 18% in extraction-condensing stations. Annual generation amounts to 7000GW of electricity and 2000GWh of district heat. Provides map of district heating network. Describes hot water and low-pressure steam systems. Treats supply to industry. Outlines plans for the future.
KEYWORDS district_heating, energy_supply_and_use, distributing, networks, heating_systems, industrial, Germany, energy_sources, combined_heat_and_power

2.

£ABNO (8400452) Germans take a liking to neighbourhood heat and power

AUTHOR Evans:J.
SOURCE *DT (Elect.Rev.) 17th February 1984, vol.214, no.6, 19-20.
ABSTRACT The availability of small highly efficient total energy (combined heat and power) units with electrical outputs up to 130 kw and heat outputs up to 250 kw make small district heating schemes feeding electricity directly into the distribution network possible. Many local authorities in West Germany are using such schemes. An example is taken of Heidenheim where there are six compact stations. These are all described. In at least two cases they are situated in housing areas. There are more than 100 compact installations in West Germany.
SOURCE £LANG E
KEYWORDS £PUBDATE (17/02/84) £DC (J)
Housing, district_heating, Germany, combined_heat_and_power, total_energy, electricity_supply

3.

£ABNO (8400436) The effects of switching from individual coal-fired stoves to central heating using district heat
/[Wirkungen der Umstellung von kohlebefeuerten Einzelofen auf Zentralheizung mit Fernwarme]

AUTHOR Jahn:A.
SOURCE *DT (Fern.Internat.) February 1984, vol.13, no.1, 36-38. 1 fig, 1 tab.
ABSTRACT Reports an investigation of the change from individual coal-fired stoves to central heating by district heat from cogeneration in West Berlin. On the basis of 48 criteria shows the effects observed in the fields of energy consumption, environment, economy, security of supply, consumers, supplier and the State. In the final section these widely differing aspects are brought together to give the total picture.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/02/84) £DC (J)
District_heating, central_heating, coal_heating, Germany, combined_heat_and_power, energy_consumption

4.

£ABNO (8400734) The answer is clear - district heating
/[Die Antwort ist naheliegend - Fernwarme]

AUTHOR Eisenhauer:G.
SOURCE *DT (Klima Kalte Heiz.) March 1984, vol.12, no.3, 97-101, 3 figs.
ABSTRACT Points to the need for West Germany to develop economical energy technologies to escape from dependence on oil. Explains how district heating preferably supplied from heat and power stations is the most economical method. Describes the advantages of district heating, the current technical position and difficulties which may arise during its introduction.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/03/84) £DC (J)
District_heating, power_stations, Germany, combined_heat_and_power

5.

£ABNO (8400787) The use of heat pumps in district heat supply
/[Der Einsatz von Warmepumpen in der Fernwarmeversorgung]

AUTHOR Winkens:H.P.
SOURCE *DT (Fern.Internat.) 1984, vol.13, no.2, 73-78, 14 figs, 1 tab, 8 refs.
ABSTRACT Predicts that heat pump heat plants will gain significance in Germany. Often it is more economical to install a large heat pump in a small district heating network than to fit a small heat pump in each house. Surveys the cost elements of heat pump heat plants and demonstrates the optimal relationship between peak load boiler and heat pump output. Shows the dependence of plant size and temperature on heat generation costs and proceeds to analyse the costs of heat distribution and heat transfer. Concludes with information on the joint function of cogeneration and heat pumps for transporting heat over great distances.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/00/84) £DC (J)
Heat_pumps, district_heating, Germany, cost, heat_flow, combined_heat_and_power

6.

£ABNO (8400789) Modularised short-distance heat systems
/[Modularisierte Nahwarme-Systeme]

AUTHOR Zacharias:F.
SOURCE *DT (Fern.Internat.) 1984, vol.13, no.2, 81-83, 3 figs, 1 tab.
ABSTRACT Heat pumps driven by combustion engines and cogeneration systems produce heat with a high degree of efficiency. In conjunction with short-distance heat distribution, large heat pumps with outputs exceeding 500 MW can be increasingly used for domestic space heating, when planning and manufacture make them cheaper and more reliable. This is feasible by standardisation, consequently the Motoren-Werk Mannheim AG and partner have worked out a concept of modularised short-distance heat. This consists of complete, pre-manufactured heating plant elements including machinery and building components.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/00/84) £DC (J)
Internal_combustion_engine_heat_pumps, heat_pumps, cost, district_heating, Germany, feasibility, efficiency, economics, space_heating, combined_heat_and_power

7.

£ABNO (8401142) Atmospheric fluidised bed combustion - application, environment and economy
/[Die atmosphärische Wirbelschichtfeuerung - Anwendung, Ökologie und Wirtschaftlichkeit]

AUTHOR Kromm:K., Schenk:H:R.
SOURCE *DT (Fern.Internat.) May 1984, vol.13, no.3, 127-131, 8 figs, 2 tabs.
ABSTRACT Notes that increasingly stringent environmental stipulations are putting at risk the use of coal in combined heat and power stations in West Germany. Demonstrates how atmospheric fluidised bed combustion is an economic and efficient method of solving the problem. Reports experience with a plant in operation since November 1979 for experimental use during the heating season.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/05/84) £DC (J)
Economics, district_heating, Germany, combined_heat_and_power, fluidised_bed_combustion, experiment, coal, environment, Germany

8.

£ABNO (8401149) The gas heat pump heating plant Maria Lindenhof in Dorsten
/[Gaswärmepumpen-Heizwerk Maria Lindenhof in Dorsten]

AUTHOR Weichsel:H.
SOURCE *DT (Fern.Internat.) May 1984, vol.13, no.3, 109-111, 5 figs, 2 tabs.
ABSTRACT Recently 'near heat systems' as opposed to district heating systems have been created for several cities and communities in West Germany. This involves the use of combined generation, for example block heat and power plants, or the use of waste or environmental heat via heat pumps to supply a large building complex or a city area. Reports on a heating plant using river water as 'cold heat source' and on the heat distribution system in the Maria Lindenhof area of Dorsten.
SOURCE £LANG G
KEYWORDS £PUBDATE (00/05/84) £DC (J)
Germany, heat_pumps, district_heating, energy_sources, combined_heat_and_power, rivers

9.

£ABNO 8403560 Planning of a remote controlled district heating with cogeneration for the town of Padua

AUTHOR Mirandola:A. et al.
SOURCE *DT (Condiz.dell Aria, Riscaldamento Refrigerazione) January 1984, vol.28, no.1, 9-23.
ABSTRACT A cogeneration plant with internal combustion engines is proposed for the district heating of Padua. A flexible system and a step-by-step execution plan are suggested, to reduce capital investments and lighten plant management during the first years. Energy saving and economic feasibility of the system are also analysed.
SOURCE £LANG I
KEYWORDS £PUBDATE (00/01/84) £DC (J)
combined_heat_and_power, Italy, economics, feasibility, energy_conservation internal_combustion_engines, district_heating

1.

£ABNO (8301101) Planning for CHP heat

AUTHOR District Heating Association
SOURCE District Heating Association Conference, Torquay 21-23 June 1983, unpriced.* 497.34.
ABSTRACT Gives the text of the 15 papers presented at the conference - The future development of CHP and DH systems in Denmark, Mortensen:H:C., The future development of CHP/DH systems in Finland, Rouhiainen:P., Eerola:H., Developing a CHP/DH system on Tyneside, Elton:L:N., CHP/DH systems and the outlook for the inner cities, Murphy:T:F., Computer aided planning of CHP/DH systems, Rosland:S., Efficiency in sizing and analysing district heating networks for city CHP schemes Usher:A:G., Rouhiainen:P., Regional grids and heat storage systems, Scholz:F., Operator experience of undergound heat main reliability in the UK, Birtles:A:B., O'Sullivan:E:F., Who Who should market CHP heat?, Murray:M:V., Who should market CHP heat?, Hutchinson:D., Who should market CHP heat? Healy:M., Private sector financing of CHP/DH schemes, Cadman:M:H., Cohen:R:L., The potential of CHP/DH as a major energy supply option for the UK, Orchard:W:R:H., Macadam:J:A., The contribution to energy conservation of a national refuse incineration/recovery policy Clennel:W:A., Lowe:D:T..
SOURCE £LANG E
KEYWORDS Denmark, Sweden, Finland, reliability, conference_proceedings, district_heating, combined_heat_and_power, UK, country, computer_aided_design, energy_storage, main_pipes, pipelines, networks, pipes, marketing, energy_conservation, refuse_incineration, heat_recovery

2.

£ABNO (8301815) Development of district heating in Finland

AUTHOR Kilpinen:U.

SOURCE *DT (Fern.Internat.) August 1983, vol.12, no.4. 199-201. 4 figs. 5 tabs.

ABSTRACT Notes how increase in population and more urbanisation have improved the prospects for district heating expansion in Finland. Treats the development of district heating since 1960. Discusses the Helsinki metropolitan area. Treats price development for heating energy, specific heat consumption of buildings, fuels, and new suppliers of district heating.

SOURCE £LANG (E)

KEYWORDS £PUBDATE (00/08/83) £DC (J)
District_heating, Finland, price, heating, buildings, combined_heat_and_power

3.

£ABNO (8400078) International conference on subsurface heat storage in theory and practice - a travel report
/[International conference on subsurface heat storage in theory and practice - ein Reisebericht]

AUTHOR Scholz:F.

SOURCE *DT (Fern.Internat.) 1983, vol.12, no.5. 295-297.

ABSTRACT On the basis of the conference proceedings gives a selective report on heat storage technology. Additionally provides information on Sweden's unique position in view of the primary energy basis for district heating and power generation.

SOURCE £LANG G

KEYWORDS £PUBDATE (00/00/83) £DC (J)
Sweden, district_heating, combined_heat_and_power, energy_storage

4.

£ABNO (8400458) The future development of district heating systems in Sweden
/[Die zukunftige Entwicklung der Fernheizsysteme in Schweden]

AUTHOR Persson:I.

SOURCE *DT (Fern.Internat.) 1983, vol.12, no.6. 324-327. 2 figs.

ABSTRACT A rapid expansion of heat and power plants is to be expected in Sweden after 1985. An output of 3000 MW (electrical) is scheduled by the year 2000, which will be accomplished in stages of 300 MW (electrical) To allow continual extension of heat and power plants accelerated expansion of the district heating networks is essential. Anticipates that this network expansion will double the connected capacity within the next 15 to 20 years. This will be achieved without any form of legislative connection obligation. In addition to district heat generation from solid fuels, heat pumps and high temperature water boilers operating with new technologies will also supply the district heating networks.

SOURCE £LANG G

KEYWORDS £PUBDATE (00/00/83) £DC (J)
Combined_heat_and_power, networks, district_heating, Sweden, heat_pumps

APPENDIX H

Soil Thermal Model "Temps" Computer Program

PURPOSE OF THE PROGRAM

The purpose of "TEMPS" is to calculate temperatures in a soil system composed of n horizontal layers using a one-dimensional finite-difference approximation technique. The model uses air temperature parameters, soil thermal parameters, initial soil temperature profile, an assumed constant temperature at the base of the soil system, and parameters defining the relationship of air temperature to surface soil temperature, to calculate daily soil temperatures at all depths for the period of interest.

The program may be used to predict depth of thaw in permafrost regions and depth of frost in non-permafrost regions for the one-dimensional case (vertical direction only).

PROGRAM FUNCTION

The function of "TEMPS" is outlined below in point form.

1. Reads thermal parameters for each soil layer.

2. Calculates finite-difference stability parameters for each layer; if these parameters are outside allowable values, program terminates with the message "Program terminated due to instability".

3. Reads air temperature and air-surface temperature parameters.

4. Calculates daily surface soil temperatures for the period of interest using a sine curve approximation.

5. Calculates predicted soil temperatures for each day over the period of interest using the finite-difference technique. Calculations are performed at each depth-increment and at each time-increment. Prints daily temperatures if requested by user.

6. Searches daily soil temperatures at each depth-increment for maximum and minimum values occurring over the period of interest. Prints maximum and minimum values.

7. Terminates.

PROGRAM INPUTS

Inputs required for operation of "TEMPS" are listed below. For theory notes and usual ranges, refer to Appendix III.

I. General parameters: line 1

1. Number of layers in soil system (max. 20); format I5
2. Number of days for model run (max. 1200); format I5
3. Time increment for model calculations (hrs); format F5.1
4. Depth increment for model calculations (cm); format F5.1
5. Depth increment for printout (cm); format F5.1
6. Control character for printing/not printing daily soil temperatures: 0 = print, 1 = no print; format I5

II. Individual layer thermal parameters: lines 2, 3, 4, ..., (n + 1) where n = number of layers. For each layer, the following parameters are required:

1. Layer thickness (cm); format F5.1
2. Unfrozen thermal conductivity (W/m-°K); format F8.5
3. Frozen thermal conductivity (W/m-°K); format F8.5
4. Unfrozen heat capacity (MJ/m^3-°K); format F8.5
5. Frozen heat capacity (MJ/m^3-°K); format F8.5
6. Range over which soil water completely freezes (°C); format F8.5. (If this valve is less than 0.5°C, program default valve is 0.5°C.)
7. Soil water content by weight (decimal fraction); format F8.5
8. Soil dry density (kg/m^3); format F8.2

III. Air and air-soil temperature parameters: line (n + 2)

1. Mean long-term annual air temperature (°C); format F5.1
2. Amplitude of air temperatures (°C); format F5.1
3. Factor for extreme winter temperatures (unitless); format F5.2
4. Displacement of air temperature sine curve (radian); format F8.5
5. Surface freezing factor (unitless); format F5.2
6. Surface thawing factor (unitless); format F5.2
7. Factor for extreme summer temperatures (unitless); format F5.2

IV. Initial soil temperature profile: lines (n + 3), (n + 4), ..., as necessary

1. Soil temperatures at all depth increments, from surface to total depth of soil system (°C); format 14F5.1 (Note: temperature at maximum depth is held constant over the modelling period).

SAMPLE INPUT DATA SET

Appendix I provides a sample data set for thermal analysis at Buffalo Narrows, Saskatchewan. In this case, there are 5 distinct soil layers, each with different thermal parameters. The total thickness of the soil system is the sum of the individual layers (645 cm). Because the depth-interval for model calculations is 15 cm, the total number of node points is (645/15) + 1 = 44. Thus the initial soil temperature profile is required at 44 points. In this case, the temperature at 645 cm depth is 3.5°C, or approximately 4°C warmer than the average annual air temperature.

SAMPLE OUTPUT FILE

Appendix II provides the output file using the sample data set given in Appendix I. The format is largely self-explanatory, and is summarized below.

1. The model is run for one year (365 days), with a depth-interval of 15 cm and a time-step of 1.2 hour.

2. Stability parameters for each layer are given using both unfrozen (SU) and frozen (SF) thermal parameters. If any of the stability parameter values exceed 0.5, the program terminates.

3. Daily surface temperatures are provided for 365 days.

4. Because the control character "1" has been used in line 1 of the input data set, the daily calculated soil temperatures are not printed.

5. Soil temperatures on the last day are printed. Note that these are identical to the starting temperatures; this indicates that the initial profile has been correctly chosen for the inputs used.

6. Maximum and minimum temperatures observed over the 365-day modelling period are printed. These can be plotted to produce the predicted cone of soil temperatures for Buffalo Narrows. In this case, temperatures less than 0°C are calculated to occur to a maximum depth of 315 cm (10.3 ft).

REQUIRED COMPUTING TIME

The central processing unit (CPU) time required to execute TEMPS is sensitive to (1) the number of days for calculations, (2) the depth-interval for model calculations, (3) the time-step for model calculations, and (4) the total thickness of the soil system.

As an example, using the sample data set and output file presented earlier:

Number of days = 365

Time-step = 1.2 hr; number of calculations at each node point = 365 * (24/1.2) = 7300

Total thickness of the soil system = 645 cm; depth-interval = 15 cm; number of node points = (645/15) + 1 = 44.

Thus the total number of calculations = 7300 * 44 = 321,200. For these conditions, the required CPU time is approximately 5.3 minutes.

Obviously, if the time-step and/or depth-increment could be increased, the required CPU time would decrease, thereby reducing program running costs. However, these parameters affect the stability parameters, which cannot exceed 0.5. The following procedure is suggested for selecting time-step and depth-increment values which will ensure a minimum of required CPU time:

1. Select the maximum reasonable depth-increment to be used. It is recommended that the depth-increment be less than the soil layer of minimum thickness.

2. For the soil thermal parameters which are to be used, run the model with the maximum possible value of time-step. As explained previously, if layer stability parameters exceed 0.5, the program terminates. Thus a trial-and-error procedure can be used to select the time-step.

Sample Input Data Set

```
    5  365  1.2  15.0  15.0    1
330.0 1.67   1.34   1.72   1.46   0.5    0.06   1760.
360.0 2.09   2.30   2.01   1.83   0.5    0.10   1900.
360.0 2.34   2.93   2.22   1.76   0.5    0.12   1840.
390.0 2.43   3.33   2.34   1.84   0.5    0.13   1860.
405.0 2.72   4.18   2.59   1.91   0.5    0.15   1920.
 -0.6 20.0 1.30 1.57080 0.80 2.00 1.00
 38.8 33.7 31.3 29.8 27.1 24.4 21.7 19.2 16.8 14.4 12.1  9.9  7.7  5.7
  3.7  1.9  0.1 -0.3 -0.3 -0.2 -0.1  0.1  0.2  0.4  0.5  0.7  0.8  1.0
  1.1  1.3  1.5  1.6  1.8  1.9  2.1  2.2  2.4  2.6  2.7  2.9  3.0  3.2
  3.3  3.5
```

Sample Output File

```
          SOIL THERMAL MODEL 'TEMPS'

INPUT DATA SET:
     NUMBER OF DAYS IN MODEL RUN =   365
     NUMBER OF LAYERS IN SYSTEM =     5
     TIME-STEP FOR MODEL CALCS  =   1.2 HR
     DEPTH-INT FOR MODEL CALCS  =  15.0 CM
     DEPTH-INT FOR PRINTOUT     =  15.0 CM

INDIVIDUAL LAYER PARAMETERS:
   LAYER  THICKNESS     KU        KF        CU        CF        BB        CC        DD
            CM        W/MK      W/MK      MJ/M3K    MJ/M3K    DEG C    UNITLESS   KG/M3
     1      30.0     1.67300   1.34000   1.72000   1.44000   0.50000   0.06000  1760.00
     2      60.0     2.09000   2.30000   2.01000   1.63000   0.50000   0.10000  1800.00
     3      60.0     2.34000   2.93000   2.22000   1.76000   0.50000   0.12000  1840.00
     4      90.0     2.43000   3.33000   2.34000   1.84000   0.50000   0.13000  1860.00
     5     405.0     2.72000   4.19000   2.59000   1.92000   0.50000   0.15000  1920.00

STABILITY PARAMETERS FOR EACH LAYER:

LAYER   1 : SU =  0.18642 ; SF =  0.17622
LAYER   2 : SU =  0.19964 ; SF =  0.27092
LAYER   3 : SU =  0.20238 ; SF =  0.31964
LAYER   4 : SU =  0.19938 ; SF =  0.34957
LAYER   5 : SU =  0.20164 ; SF =  0.41800

LATENT HEAT (MJ/KG) OF EACH LAYER:
LAYER   1 : LAT HEAT =   35.376
LAYER   2 : LAT HEAT =   60.300
LAYER   3 : LAT HEAT =   73.768
LAYER   4 : LAT HEAT =   81.003
LAYER   5 : LAT HEAT =   96.480

AIR AND SURFACE TEMPERATURE PARAMETERS:

     AVERAGE ANNUAL AIR TEMP =  -0.6 DEG C
     AMPLITUDE OF SINE CURVE =  20.0 DEG C
     DISPLACEM OF SINE CURVE =  1.57080 RADIAN
     FACTOR FOR EXTREME WINTER TEMPS =  1.00 (UNITLESS)
     FACTOR FOR EXTREME SUMMER TEMPS =  1.00 (UNITLESS)
     FREEZING SURFACE TRANSFER FACTOR =  0.80 (UNITLESS)
     THAWING SURFACE TRANSFER FACTOR  =  2.00 (UNITLESS)
```

... CONT'D ...

```
SURFACE TEMPERATURES FROM SINE CURVE:

   (INCLUD EXTREME W/ FREEZE/ THAW FACTORS)


 38.8 38.8 38.7 38.7 38.7 38.6 38.5 38.4 38.3 38.2 38.1 37.9 37.8 37.6
 37.5 37.3 37.1 36.9 36.7 36.5 36.2 36.0 35.7 35.4 35.2 34.9 34.6 34.2
 33.9 33.6 33.2 32.9 32.5 32.1 31.8 31.4 31.0 30.5 30.1 29.7 29.2 28.8
 28.3 27.7 27.4 26.9 26.4 25.9 25.4 24.9 24.4 23.8 23.3 22.7 22.2 21.6
 21.0 20.5 19.9 19.3 18.7 18.1 17.5 16.9 16.3 15.6 15.0 14.4 13.7 13.1
 12.5 11.8 11.2 10.5  9.8  9.2  8.5  7.8  7.2  6.5  5.8  5.1  4.5  3.8
  3.1  2.4  1.7  1.0  0.3 -0.4 -0.4 -0.7 -1.0 -1.2 -1.5 -1.8 -2.1 -2.3
 -2.6 -2.9 -3.2 -3.4 -3.7 -4.0 -4.2 -4.5 -4.8 -5.0 -5.3 -5.6 -5.8 -6.1
 -6.3 -6.6 -6.8 -7.1 -7.3 -7.6 -7.8 -8.1 -8.3 -8.6 -8.8 -9.0 -9.3 -9.5
 -9.7 -9.9-10.2-10.4-10.6-10.8-11.0-11.2-11.4-11.6-11.8-12.0-12.2-12.4
-12.6-12.7-12.9-13.1-13.3-13.4-13.6-13.7-13.9-14.0-14.2-14.3-14.5-14.6
-14.7-14.8-15.0 15.1-15.2-15.3-15.4-15.5 15.6-15.7-15.8-15.8-15.9-16.0
-16.0-16.1-16.2-16.2-16.3-16.3-16.3-16.4-16.4-16.4-16.3-16.5-16.5-16.5
-16.5-16.5-16.5-16.5-16.4-16.4-16.4-16.3-16.3-16.3-16.2-16.2-16.1-16.1
-16.0-15.9-15.8-15.8-15.7-15.6-15.5-15.4-15.3-15.2-15.1-15.0-14.8-14.7
-14.6-14.5-14.3-14.2-14.0 13.9-13.7-13.6-13.4-13.3-13.1-12.9-12.7-12.6
-12.4-12.2-12.0-11.8-11.6-11.4-11.2-11.0-10.8-10.6-10.4-10.2 -9.9 -9.7
 -9.5 -9.3 -9.0 -8.8 -8.6 -8.3 -8.1 -7.8 -7.6 -7.3 -7.1 -6.8 -6.6 -6.3
 -6.1 -5.8 -5.6 -5.3 -5.0 -4.8 -4.5 -4.2 -4.0 -3.7 -3.4 -3.2 -2.9 -2.6
 -2.3 -2.1 -1.8 -1.5 -1.2 -1.0 -0.7 -0.4 -0.1  0.3  1.0  1.7  2.4  3.1
  3.8  4.5  5.1  5.8  6.5  7.2  7.8  8.5  9.2  9.8 10.5 11.2 11.8 12.5
 13.1 13.7 14.4 15.0 15.6 16.3 16.9 17.5 18.1 18.7 19.3 19.9 20.5 21.0
 21.6 22.2 22.7 23.3 23.8 24.3 24.9 25.4 25.9 26.4 26.9 27.4 27.9 28.3
 28.8 29.2 29.7 30.1 30.5 31.0 31.4 31.8 32.1 32.5 32.9 33.2 33.6 33.9
 34.2 34.6 34.9 35.2 35.4 35.7 36.0 36.2 36.5 36.7 36.9 37.1 37.3 37.5
 37.6 37.8 37.9 38.1 38.2 38.3 38.4 38.5 38.6 38.7 38.7 38.7 38.8 38.8
 38.8

AVERAGE OF LISTED TEMPERATURES =   6.8 DEG C

    THAWING INDEX (DEG C) FOR ALL DAYS =  4430.4
    FREEZING INDEX (DEG C) FOR ALL DAYS = -1947.4
    NODE POINTS =   3 AT BOTTOM OF LAYER   1
    NODE POINTS =   7 AT BOTTOM OF LAYER   2
    NODE POINTS =  11 AT BOTTOM OF LAYER   3
    NODE POINTS =  17 AT BOTTOM OF LAYER   4
    NODE POINTS =  44 AT BOTTOM OF LAYER   5

TOTAL THICKNESS OF SOIL SYSTEM =   645.00 CM
TOTAL NUMBER OF NODE POINTS =  44

INITIAL SOIL TEMP PROFILE IN DEG C:
 38.8 35.7 32.8 29.8 27.1 24.4 21.7 19.2 16.8 14.4 12.1  9.9  7.7  5.7
  3.7  1.9  0.1 -0.3 -0.3 -0.2 -0.1  0.1  0.2  0.4  0.5  0.7  0.8  1.0
  1.1  1.3  1.5  1.6  1.8  1.9  2.1  2.2  2.4  2.6  2.7  2.9  3.0  3.2
  3.3  3.5


*****END OF INPUT DATA SET*****************
```

... CONT'D...

```
CALCULATED SOIL TEMPS AT  15.0 CM INTERVALS, FROM DAY 2 TO DAY   362

***USER HAS REQUESTED THAT THESE NOT BE PRINTED***


SOIL TEMPERATURES ON LAST DAY:

 38.8 35.7 32.5 29.8 27.0 24.3 21.7 19.2 16.8 14.4 12.3  9.8  7.6  5.6
  3.6  1.6  0.1 -0.3 -3.3 -0.2 -0.1  0.0  0.2  0.3  0.5  0.7  0.8  1.0
  1.1  1.3  1.4  1.6  1.8  1.9  2.1  2.2  2.4  2.5  2.7  2.9  3.0  3.2
  3.3  3.5

MAXIMUM AND MINIMUM TEMPERATURES OBSERVED:

 38.8 35.7 32.8 30.2 27.8 25.6 23.8 22.3 21.0 19.8 18.8 17.8 16.9 16.1
 15.3 14.6 13.9 13.3 12.8 12.3 11.8 11.3 10.9 10.5 10.1  9.7  9.3  8.9
  8.6  8.2  7.9  7.5  7.2  6.8  6.5  6.2  5.8  5.5  5.2  4.8  4.5  4.2
  3.8  3.5
-16.5-14.7-12.9-11.7-10.6 -9.4 -6.4 -7.5 -6.6 -5.7 -5.0 -4.2 -3.6 -2.9
 -2.3 -1.8 -1.3 -0.9 -0.6 -0.4 -0.2  0.0  0.1  0.3  0.5  0.6  0.8  0.9
  1.1  1.3  1.4  1.6  1.7  1.9  2.1  2.2  2.4  2.5  2.7  2.9  3.0  3.2
  3.3  3.5

AVERAGE TEMPERATURE AT EACH NODE:

  6.7  6.4  6.2  5.9  5.5  5.2  5.0  4.7  4.4  4.2  4.0  3.8  3.7  3.6
  3.4  3.4  3.3  3.2  3.2  3.2  3.2  3.2  3.2  3.3  3.3  3.3  3.3  3.3
  3.3  3.3  3.3  3.4  3.4  3.4  3.4  3.4  3.4  3.4  3.4  3.4  3.5  3.5
  3.5  3.5

AVERAGE TEMPERATURE FOR SOIL SYSTEM =  3.9 DEG C
```

... END OF OUTPUT.

THEORY NOTES AND USUAL PARAMETER RANGES

I. GENERAL PARAMETERS

1. Number of layers: user-selected; maximum allowable 20.

2. Number of days: the program should be run at least 365 days to ensure that the soil temperature profile returns to a good approximation of the initial (assumed) profile. If it does not, the program should be run again using the derived profile as a starting value.

3. Time increment: as explained, this value is interrelated with the depth increment in determining the stability of the program solution. Time increment is normally 0.5 to 4.0 hr.

4. Depth increment: this value is interrelated with the time increment in determining the stability of the program solution; however, the chosen depth increment should recognize the thickness of the narrowest soil layer. It is suggested that the depth increment be 1/2 the size of the narrowest layer. Layer thicknesses and depth increment should be selected such that node points fall at layer interfaces.

5. Depth increment for printout: normally this value is set equal to the depth increment for model calculations. The user may choose to have these values unequal; the depth increment for printout must be greater than the depth increment for calculations by an integral factor (i.e. 1X or 2X).

6. Print/not print daily soil temperatures: this is the user's choice. Daily soil temperatures for the soil layer may be used to generate plots of iso-temperature lines as a function of time; the user should recognize, however, that printing daily soil temperatures each day for a year will produce a large output.

II. INDIVIDUAL LAYER THERMAL PARAMETERS

1. Layer thickness: may be different for all layers. As mentioned, the layer thickness should be divisible by the depth increment for model calculations in order that node points fall at layer interfaces.

2. Unfrozen thermal conductivity: affected by soil particle size and moisture content. Charts published in Geotechnical Engineering for Cold Regions (Andersland and Anderson, 1978) and Cold Climate Utilities Delivery Design Manual. Usual range 0.5 to 2.5 W/m-°K for sandy soils, 0.2 to 1.8 W/m-°K for fine grained soils. Conversion factors to W/m-°K: BTU/ft-hr-°F * 1.73; mcal/cm-sec-°C * 0.4184.

3. Frozen thermal conductivity: usual range 0.2 to 4.0 W/m-°K for sandy soils, 0.2 to 2.2 W/m-°K for fine grained soils. Otherwise as (2) above.

4. Unfrozen heat capacity: in this program, the heat capacity is expressed on a unit volume basis. Andersland and Anderson (1978) provides equations for calculation of heat capacity. Values are affected by soil dry density and moisture content. Usual range 0.8 to 3.2 MJ/m^3-°K.
Conversion factors to MJ/m^3-°K:
BTU/ft^3-°F * 0.067; cal/cm^3-°C * 4.184.

5. Frozen heat capacity: Usual range 0.8 to 2.2 MJ/m^3-°K. Otherwise as (4) above.

6. Range over which soil water completely freezes: a function of the soil particle size. Due to absorption onto soil particle surfaces, not all soil moisture freezes at 0°C. See Andersland and Anderson (1978) for theory. Usual range 0 to 10°C. If a value less than 0.5°C is input, the program default value of 0.5°C is used. (Note that input of a value such as 5°C means that the soil moisture freezes in the range of 0°C to -5°C and that it is defined as completely frozen when colder than -5°C).

7. Soil water content by weight: defined as the moisture content of the soil (by weight) expressed as a fraction of the weight of the soil particles, i.e. wc = Ww/Ws.

8. Soil dry density: self-explanatory, expressed as kg/m^3.

III. AIR AND AIR-SOIL TEMPERATURE PARAMETERS

1. Mean annaul air temperature: available from the Canadian Hydrologic Atlas, Canadian Climatic Maps; also occasionally provided in engineering reports on the region of interest.

2. Amplitude of air temperatures: after obtaining and plotting mean monthly air temperatures from the Canadian Climatic Maps, determine the amplitude from the mean annual temperature.

3. Factor for extreme winter temperatures: defined as (total degree-days below 0°C in an extreme winter) divided by (total degree-days below 0°C in an average winter). A study undertaken in Fort McPherson, N.W.T. suggests a value of 1.25. Range not established.

4. Displacement of air temperature sine curve: this parameter sets the time at which the air temperature sine curve is initialized. If 1.5708 is used, the curve will initialize at the maximum yearly temperature.

5. Surface freezing factor: relationship between winter air temperatures and winter soil surface temperatures. For theory and values, refer to Andersland and Anderson (1978) and Cold Climate Utilities Delivery Design Manual (p. 15-57). Usual values: snow 1.0; sand and gravel 0.9; turf 0.5; stripped mineral soil 0.33.

6. Surface thawing factor: relationship between summer air temperatures and summer soil surface temperatures. Usual values: sand and gravel 1.5; turf 1.0; stripped mineral soil 1.72 to 1.26. Otherwise see (5) above.

7. Factor for extreme summer temperatures: defined as (total degree-days above 0°C in an extreme summer) divided by (total degree-days above 0°C in an average summer). Range not established.

REFERENCES*

Andersland, O.B. and D.M. Anderson, editors (1978). Geotechnical Engineering for Cold Regions. New York: McGraw-Hill. 566 pp.

Cold Climate Utilities Delivery Design Manual. (1979). Environmental Protection Service Report No. EPS 3-WP-79-2.

Canadian Climatic Maps (1967). Canadian Department of Transport, Meteorological Branch.

Hydrologic Atlas of Canada (1978). Supply and Services Canada Cat. No. EN 37-26/1978.

*All references listed are available at AESL Library.

APPENDIX I

Present Worth Computer Analysis

WOLLASTON -ALL FACILITIES-1000H-8MONTH HEATING SEASON

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-320074.
PUMP COS	13.0	7.8	-101745.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-104301.
HEAT SALES	13.0	6.0	785059.

TOTAL PRESENT WORTH OF PROJECT -$ 258940.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	-350000.	-6700.	0.	-7000.	59500.
1987	0.	-6700.	0.	-7000.	63000.
1988	0.	-6700.	0.	-7000.	66500.
1989	0.	-6700.	0.	-7000.	70000.
1990	0.	-6700.	0.	-7000.	73500.
1991	0.	-6700.	0.	-7000.	77000.
1992	0.	-6700.	0.	-7000.	80500.
1993	0.	-6700.	0.	-7000.	84000.
1994	0.	-6700.	0.	-7000.	87500.
1995	0.	-6700.	0.	-7000.	91000.
1996	0.	-6700.	0.	-7000.	94500.
1997	0.	-6700.	0.	-7000.	98000.
1998	0.	-6700.	0.	-7000.	101500.
1999	0.	-6700.	0.	-7000.	105000.
2000	0.	-6700.	0.	-7000.	108500.
2001	-5000.	-6700.	0.	-7000.	112000.
2002	0.	-6700.	0.	-7000.	115500.
2003	0.	-6700.	0.	-7000.	119000.
2004	0.	-6700.	0.	-7000.	122500.
2005	0.	-6700.	0.	-7000.	126000.
2006	0.	-6700.	0.	-7000.	129500.
2007	0.	-6700.	0.	-7000.	133000.
2008	0.	-6700.	0.	-7000.	136500.
2009	0.	-6700.	0.	-7000.	140000.
2010	0.	-6700.	0.	-7000.	143500.
2011	0.	-6700.	0.	-7000.	147000.
2012	0.	-6700.	0.	-7000.	150500.
2013	0.	-6700.	0.	-7000.	154000.
2014	0.	-6700.	0.	-7000.	157500.
2015	0.	-6700.	0.	-7000.	161000.
2016	0.	-6700.	0.	-7000.	164500.

WOLLASTON -ALL FACILITIES-1000H-8MONTH HEATING SEASON

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-320074.
PUMP COS	13.0	7.8	-101745.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-104301.
HEAT SALES	13.0	10.0	1321374.

TOTAL PRESENT WORTH OF PROJECT -$ 793255.

2001	-5000.	-5000.	0.	-7000.	56000.
2002	0.	-5000.	0.	-7000.	57000.
2003	0.	-5000.	0.	-7000.	57500.
2004	0.	-5000.	0.	-7000.	58000.
2005	0.	-5000.	0.	-7000.	58500.
2006	0.	-5000.	0.	-7000.	59000.
2007	0.	-5000.	0.	-7000.	59500.
2008	0.	-5000.	0.	-7000.	60000.
2009	0.	-5000.	0.	-7000.	60500.
2010	0.	-5000.	0.	-7000.	61000.
2011	0.	-5000.	0.	-7000.	61500.
2012	0.	-5000.	0.	-7000.	62000.
2013	0.	-5000.	0.	-7000.	62500.
2014	0.	-5000.	0.	-7000.	63000.
2015	0.	-5000.	0.	-7000.	63500.
2016	0.	-5000.	0.	-7000.	64000.

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WOLLASTON-ALL FACILITIES-1000H-BASE DATA

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-320074.
PUMP COS	13.0	7.8	-75929.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-106301.
HEAT SALES	13.0	6.0	662576.

TOTAL PRESENT WORTH OF PROJECT -$ 160273.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	-350000.	-5000.	0.	-7000.	49000.
1987	0.	-5000.	0.	-7000.	49500.
1988	0.	-5000.	0.	-7000.	50000.
1989	0.	-5000.	0.	-7000.	50500.
1990	0.	-5000.	0.	-7000.	51000.
1991	0.	-5000.	0.	-7000.	51500.
1992	0.	-5000.	0.	-7000.	52000.
1993	0.	-5000.	0.	-7000.	52500.
1994	0.	-5000.	0.	-7000.	53000.
1995	0.	-5000.	0.	-7000.	53500.
1996	0.	-5000.	0.	-7000.	54000.
1997	0.	-5000.	0.	-7000.	54500.
1998	0.	-5000.	0.	-7000.	55000.
1999	0.	-5000.	0.	-7000.	55500.
2000	0.	-5000.	0.	-7000.	56000.
2001	-5000.	-5000.	0.	-7000.	56500.
2002	0.	-5000.	0.	-7000.	57000.
2003	0.	-5000.	0.	-7000.	57500.
2004	0.	-5000.	0.	-7000.	58000.
2005	0.	-5000.	0.	-7000.	58500.
2006	0.	-5000.	0.	-7000.	59000.
2007	0.	-5000.	0.	-7000.	59500.
2008	0.	-5000.	0.	-7000.	60000.
2009	0.	-5000.	0.	-7000.	60500.
2010	0.	-5000.	0.	-7000.	61000.
2011	0.	-5000.	0.	-7000.	61500.
2012	0.	-5000.	0.	-7000.	62000.
2013	0.	-5000.	0.	-7000.	62500.
2014	0.	-5000.	0.	-7000.	63000.
2015	0.	-5000.	0.	-7000.	63500.
2016	0.	-5000.	0.	-7000.	64000.

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WOLLASTON-ALL FACILITIES-1000H-BASE DATA

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-320074.
PUMP COS	13.0	7.8	-75929.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-106301.
HEAT SALES	13.0	10.0	1119440.

TOTAL PRESENT WORTH OF PROJECT -$ 617137.

$

1999	0.	-5000.	0.	-7000.	53500.
2000	0.	-5000.	0.	-7000.	54000.
2001	0.	-5000.	0.	-7000.	54500.
2002	0.	-5000.	0.	-7000.	55000.
2003	0.	-5000.	0.	-7000.	55500.
2004	0.	-5000.	0.	-7000.	56000.
2005	0.	-5000.	0.	-7000.	56500.
2006	-5000.	-5000.	0.	-7000.	57000.
2007	0.	-5000.	0.	-7000.	57500.
2008	0.	-5000.	0.	-7000.	58000.
2009	0.	-5000.	0.	-7000.	58500.
2010	0.	-5000.	0.	-7000.	59000.
2011	0.	-5000.	0.	-7000.	59500.
2012	0.	-5000.	0.	-7000.	60000.
2013	0.	-5000.	0.	-7000.	60500.
2014	0.	-5000.	0.	-7000.	61000.
2015	0.	-5000.	0.	-7000.	61500.
2016	0.	-5000.	0.	-7000.	62000.
2017	0.	-5000.	0.	-7000.	62500.
2018	0.	-5000.	0.	-7000.	63000.
2019	0.	-5000.	0.	-7000.	63500.
2020	0.	-5000.	0.	-7000.	64000.
2021	0.	-5000.	0.	-7000.	

WOLLASTON-ALL FACILITIES-1000M-5 YEAR DEFERRAL

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-252068.
PUMP COS	13.0	7.8	-59994.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-83992.
HEAT SALES	13.0	6.0	481253.

TOTAL PRESENT WORTH OF PROJECT =$ 85198.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	0.	0.	0.	0.	0.
1987	0.	0.	0.	0.	0.
1988	0.	0.	0.	0.	0.
1989	0.	0.	0.	0.	0.
1990	0.	0.	0.	-7000.	49000.
1991	-350000.	-5000.	0.	-7000.	49500.
1992	0.	-5000.	0.	-7000.	50000.
1993	0.	-5000.	0.	-7000.	50500.
1994	0.	-5000.	0.	-7000.	51000.
1995	0.	-5000.	0.	-7000.	51500.
1996	0.	-5000.	0.	-7000.	52000.
1997	0.	-5000.	0.	-7000.	52500.
1998	0.	-5000.	0.	-7000.	53000.
1999	0.	-5000.	0.	-7000.	53500.
2000	0.	-5000.	0.	-7000.	54000.
2001	0.	-5000.	0.	-7000.	54500.
2002	0.	-5000.	0.	-7000.	55000.
2003	0.	-5000.	0.	-7000.	55500.
2004	0.	-5000.	0.	-7000.	56000.
2005	0.	-5000.	0.	-7000.	56500.
2006	-5000.	-5000.	0.	-7000.	57000.
2007	0.	-5000.	0.	-7000.	57500.
2008	0.	-5000.	0.	-7000.	58000.
2009	0.	-5000.	0.	-7000.	58500.
2010	0.	-5000.	0.	-7000.	59000.
2011	0.	-5000.	0.	-7000.	59500.
2012	0.	-5000.	0.	-7000.	60000.
2013	0.	-5000.	0.	-7000.	60500.
2014	0.	-5000.	0.	-7000.	61000.
2015	0.	-5000.	0.	-7000.	61500.
2016	0.	-5000.	0.	-7000.	62000.
2017	0.	-5000.	0.	-7000.	62500.
2018	0.	-5000.	0.	-7000.	63000.
2019	0.	-5000.	0.	-7000.	63500.
2020	0.	-5000.	0.	-7000.	64000.
2021	0.	-5000.	0.	-7000.	

WOLLASTON-ALL FACILITIES-1000M-5 YEAR DEFERRAL

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-252068.
PUMP COS	13.0	7.8	-59994.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-83992.
HEAT SALES	13.0	10.0	978526.

TOTAL PRESENT WORTH OF PROJECT =$ 582471.

2003	0.	-6000.	0.	-8400.	57500.
2004	0.	-6000.	0.	-8400.	58000.
2005	0.	-6000.	0.	-8400.	58500.
2006	0.	-6000.	0.	-8400.	59000.
2007	0.	-6000.	0.	-8400.	59500.
2008	0.	-6000.	0.	-8400.	60000.
2009	0.	-6000.	0.	-8400.	60500.
2010	0.	-6000.	0.	-8400.	61000.
2011	0.	-6000.	0.	-8400.	61500.
2012	0.	-6000.	0.	-8400.	62000.
2013	0.	-6000.	0.	-8400.	62500.
2014	0.	-6000.	0.	-8400.	63000.
2015	0.	-6000.	0.	-8400.	63500.
2016	0.	-6000.	0.	-8400.	64000.

1

WOLLASTON-ALL FACILITIES-WORST CASE-BASE DATA-1000M-15%CAP INCR $20% OF COS

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-368642.
PUMP COS	13.0	7.8	-91115.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-127561.
HEAT SALES	13.0	6.0	662576.

TOTAL PRESENT WORTH OF PROJECT -$ 75259.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	-403000.	-6000.	0.	-8400.	49000.
1987	0.	-6000.	0.	-8400.	49500.
1988	0.	-6000.	0.	-8400.	50000.
1989	0.	-6000.	0.	-8400.	50500.
1990	0.	-6000.	0.	-8400.	51000.
1991	0.	-6000.	0.	-8400.	51500.
1992	0.	-6000.	0.	-8400.	52000.
1993	0.	-6000.	0.	-8400.	52500.
1994	0.	-6000.	0.	-8400.	53000.
1995	0.	-6000.	0.	-8400.	53500.
1996	0.	-6000.	0.	-8400.	54000.
1997	0.	-6000.	0.	-8400.	54500.
1998	0.	-6000.	0.	-8400.	55000.
1999	0.	-6000.	0.	-8400.	55500.
2000	0.	-6000.	0.	-8400.	56000.
2001	-6000.	-6000.	0.	-8400.	56500.
2002	0.	-6000.	0.	-8400.	57000.
2003	0.	-6000.	0.	-8400.	57500.
2004	0.	-6000.	0.	-8400.	58000.
2005	0.	-6000.	0.	-8400.	58500.
2006	0.	-6000.	0.	-8400.	59000.
2007	0.	-6000.	0.	-8400.	59500.
2008	0.	-6000.	0.	-8400.	60000.
2009	0.	-6000.	0.	-8400.	60500.
2010	0.	-6000.	0.	-8400.	61000.
2011	0.	-6000.	0.	-8400.	61500.
2012	0.	-6000.	0.	-8400.	62000.
2013	0.	-6000.	0.	-8400.	62500.
2014	0.	-6000.	0.	-8400.	63000.
2015	0.	-6000.	0.	-8400.	63500.
2016	0.	-6000.	0.	-8400.	64000.

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WOLLASTON-ALL FACILITIES-WORST CASE-BASE DATA-1000M-15%CAP INCR $20% OF COS

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-368642.
PUMP COS	13.0	7.8	-91115.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-127561.
HEAT SALES	13.0	10.0	1119440.

TOTAL PRESENT WORTH OF PROJECT -$ 532123.

2003	0.	-1700.	0.	-4500.	35000.
2004	0.	-1700.	0.	-4500.	35000.
2005	0.	-1700.	0.	-4500.	35000.
2006	0.	-1700.	0.	-4500.	35000.
2007	0.	-1700.	0.	-4500.	35000.
2008	0.	-1700.	0.	-4500.	35000.
2009	0.	-1700.	0.	-4500.	35000.
2010	0.	-1700.	0.	-4500.	35000.
2011	0.	-1700.	0.	-4500.	35000.
2012	0.	-1700.	0.	-4500.	35000.
2013	0.	-1700.	0.	-4500.	35000.
2014	0.	-1700.	0.	-4500.	35000.
2015	0.	-1700.	0.	-4500.	35000.
2016	0.	-1700.	0.	-4500.	35000.

1

WOLLASTON-SCHOOL ONLY-1000M-8 MONTH HEATING SEASON

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-202039.
PUMP COS	13.0	7.8	-25816.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-68336.
HEAT SALES	13.0	6.0	428690.

TOTAL PRESENT WORTH OF PROJECT -$ 132499.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	-221000.	-1700.	0.	-4500.	35000.
1987	0.	-1700.	0.	-4500.	35000.
1988	0.	-1700.	0.	-4500.	35000.
1989	0.	-1700.	0.	-4500.	35000.
1990	0.	-1700.	0.	-4500.	35000.
1991	0.	-1700.	0.	-4500.	35000.
1992	0.	-1700.	0.	-4500.	35000.
1993	0.	-1700.	0.	-4500.	35000.
1994	0.	-1700.	0.	-4500.	35000.
1995	0.	-1700.	0.	-4500.	35000.
1996	0.	-1700.	0.	-4500.	35000.
1997	0.	-1700.	0.	-4500.	35000.
1998	0.	-1700.	0.	-4500.	35000.
1999	0.	-1700.	0.	-4500.	35000.
2000	0.	-1700.	0.	-4500.	35000.
2001	-3000.	-1700.	0.	-4500.	35000.
2002	0.	-1700.	0.	-4500.	35000.
2003	0.	-1700.	0.	-4500.	35000.
2004	0.	-1700.	0.	-4500.	35000.
2005	0.	-1700.	0.	-4500.	35000.
2006	0.	-1700.	0.	-4500.	35000.
2007	0.	-1700.	0.	-4500.	35000.
2008	0.	-1700.	0.	-4500.	35000.
2009	0.	-1700.	0.	-4500.	35000.
2010	0.	-1700.	0.	-4500.	35000.
2011	0.	-1700.	0.	-4500.	35000.
2012	0.	-1700.	0.	-4500.	35000.
2013	0.	-1700.	0.	-4500.	35000.
2014	0.	-1700.	0.	-4500.	35000.
2015	0.	-1700.	0.	-4500.	35000.
2016	0.	-1700.	0.	-4500.	35000.

1

WOLLASTON-SCHOOL ONLY-1000M-8 MONTH HEATING SEASON

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-202039.
PUMP COS	13.0	7.8	-25816.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-68336.
HEAT SALES	13.0	10.0	704748.

TOTAL PRESENT WORTH OF PROJECT -$ 410577.

1

2002	0.	-1300.	0.	-4500.	30000.
2003	0.	-1300.	0.	-4500.	30000.
2004	0.	-1300.	0.	-4500.	30000.
2005	0.	-1300.	0.	-4500.	30000.
2006	0.	-1300.	0.	-4500.	30000.
2007	0.	-1300.	0.	-4500.	30000.
2008	0.	-1300.	0.	-4500.	30000.
2009	0.	-1300.	0.	-4500.	30000.
2010	0.	-1300.	0.	-4500.	30000.
2011	0.	-1300.	0.	-4500.	30000.
2012	0.	-1300.	0.	-4500.	30000.
2013	0.	-1300.	0.	-4500.	30000.
2014	0.	-1300.	0.	-4500.	30000.
2015	0.	-1300.	0.	-4500.	30000.
2016	0.	-1300.	0.	-4500.	30000.

1

WOLLASTON-SCHOOL ONLY-1000H-BASE DATA

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-202039.
PUMP COS	13.0	7.8	-19742.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-68336.
HEAT SALES	13.0	6.0	367448.

TOTAL PRESENT WORTH OF PROJECT -$ 77331.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	-221000.	-1300.	0.	-4500.	30000.
1987	0.	-1300.	0.	-4500.	30000.
1988	0.	-1300.	0.	-4500.	30000.
1989	0.	-1300.	0.	-4500.	30000.
1990	0.	-1300.	0.	-4500.	30000.
1991	0.	-1300.	0.	-4500.	30000.
1992	0.	-1300.	0.	-4500.	30000.
1993	0.	-1300.	0.	-4500.	30000.
1994	0.	-1300.	0.	-4500.	30000.
1995	0.	-1300.	0.	-4500.	30000.
1996	0.	-1300.	0.	-4500.	30000.
1997	0.	-1300.	0.	-4500.	30000.
1998	0.	-1300.	0.	-4500.	30000.
1999	0.	-1300.	0.	-4500.	30000.
2000	0.	-1300.	0.	-4500.	30000.
2001	-3000.	-1300.	0.	-4500.	30000.
2002	0.	-1300.	0.	-4500.	30000.
2003	0.	-1300.	0.	-4500.	30000.
2004	0.	-1300.	0.	-4500.	30000.
2005	0.	-1300.	0.	-4500.	30000.
2006	0.	-1300.	0.	-4500.	30000.
2007	0.	-1300.	0.	-4500.	30000.
2008	0.	-1300.	0.	-4500.	30000.
2009	0.	-1300.	0.	-4500.	30000.
2010	0.	-1300.	0.	-4500.	30000.
2011	0.	-1300.	0.	-4500.	30000.
2012	0.	-1300.	0.	-4500.	30000.
2013	0.	-1300.	0.	-4500.	30000.
2014	0.	-1300.	0.	-4500.	30000.
2015	0.	-1300.	0.	-4500.	30000.
2016	0.	-1300.	0.	-4500.	30000.

1

WOLLASTON-SCHOOL ONLY-1000H-BASE DATA

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-202039.
PUMP COS	13.0	7.8	-19742.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-68336.
HEAT SALES	13.0	10.0	605802.

TOTAL PRESENT WORTH OF PROJECT -$ 315685.

2001	-5000.	-1300.	0.	-4500.	30000.
2002	0.	-1300.	0.	-4500.	30000.
2003	0.	-1300.	0.	-4500.	30000.
2004	0.	-1300.	0.	-4500.	30000.
2005	0.	-1300.	0.	-4500.	30000.
2006	0.	-1300.	0.	-4500.	30000.
2007	0.	-1300.	0.	-4500.	30000.
2008	0.	-1300.	0.	-4500.	30000.
2009	0.	-1300.	0.	-4500.	30000.
2010	0.	-1300.	0.	-4500.	30000.
2011	0.	-1300.	0.	-4500.	30000.
2012	0.	-1300.	0.	-4500.	30000.
2013	0.	-1300.	0.	-4500.	30000.
2014	0.	-1300.	0.	-4500.	30000.
2015	0.	-1300.	0.	-4500.	30000.
2016	0.	-1300.	0.	-4500.	30000.

1

WOLLASTON-SCHOOLONLY-1000H-CAP COSTS INCREASED 15%

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-232846.
PUMP COS	13.0	7.8	-19742.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-68336.
HEAT SALES	13.0	6.0	367448.

TOTAL PRESENT WORTH OF PROJECT -$ 46525.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	-254000.	-1300.	0.	-4500.	30000.
1987	0.	-1300.	0.	-4500.	30000.
1988	0.	-1300.	0.	-4500.	30000.
1989	0.	-1300.	0.	-4500.	30000.
1990	0.	-1300.	0.	-4500.	30000.
1991	0.	-1300.	0.	-4500.	30000.
1992	0.	-1300.	0.	-4500.	30000.
1993	0.	-1300.	0.	-4500.	30000.
1994	0.	-1300.	0.	-4500.	30000.
1995	0.	-1300.	0.	-4500.	30000.
1996	0.	-1300.	0.	-4500.	30000.
1997	0.	-1300.	0.	-4500.	30000.
1998	0.	-1300.	0.	-4500.	30000.
1999	0.	-1300.	0.	-4500.	30000.
2000	0.	-1300.	0.	-4500.	30000.
2001	-5000.	-1300.	0.	-4500.	30000.
2002	0.	-1300.	0.	-4500.	30000.
2003	0.	-1300.	0.	-4500.	30000.
2004	0.	-1300.	0.	-4500.	30000.
2005	0.	-1300.	0.	-4500.	30000.
2006	0.	-1300.	0.	-4500.	30000.
2007	0.	-1300.	0.	-4500.	30000.
2008	0.	-1300.	0.	-4500.	30000.
2009	0.	-1300.	0.	-4500.	30000.
2010	0.	-1300.	0.	-4500.	30000.
2011	0.	-1300.	0.	-4500.	30000.
2012	0.	-1300.	0.	-4500.	30000.
2013	0.	-1300.	0.	-4500.	30000.
2014	0.	-1300.	0.	-4500.	30000.
2015	0.	-1300.	0.	-4500.	30000.
2016	0.	-1300.	0.	-4500.	30000.

1

WOLLASTON-SCHOOLONLY-1000H-CAP COSTS INCREASED 15%

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-232846.
PUMP COS	13.0	7.8	-19742.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-68336.
HEAT SALES	13.0	10.0	405802.

TOTAL PRESENT WORTH OF PROJECT -$ 284878.

2000	0.	-1400.	0.	-5300.	30000.
2001	-5000.	-1400.	0.	-5300.	30000.
2002	0.	-1400.	0.	-5300.	30000.
2003	0.	-1400.	0.	-5300.	30000.
2004	0.	-1400.	0.	-5300.	30000.
2005	0.	-1400.	0.	-5300.	30000.
2006	0.	-1400.	0.	-5300.	30000.
2007	0.	-1400.	0.	-5300.	30000.
2008	0.	-1400.	0.	-5300.	30000.
2009	0.	-1400.	0.	-5300.	30000.
2010	0.	-1400.	0.	-5300.	30000.
2011	0.	-1400.	0.	-5300.	30000.
2012	0.	-1400.	0.	-5300.	30000.
2013	0.	-1400.	0.	-5300.	30000.
2014	0.	-1400.	0.	-5300.	30000.
2015	0.	-1400.	0.	-5300.	30000.
2016	0.	-1400.	0.	-5300.	30000.

OLLASTON-SCHOOL ONLY-1000H-CAPITAL COSTTINCRE BY 15% AND ANNUAL EXP UP

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-232846.
PUMP COS	13.0	7.8	-24297.
HEAT LOSS	13.0	6.0	0.
MAINT	13.0	7.8	-80485.
T SALES	13.0	6.0	367448.

TOTAL PRESENT WORTH OF PROJECT -1 29821.

YEAR	CAP COS	PUMP COS	HEAT LOSS	MAINT	HEAT SALES
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	-234000.	-1400.	0.	-5300.	30000.
1987	0.	-1400.	0.	-5300.	30000.
1988	0.	-1400.	0.	-5300.	30000.
1989	0.	-1400.	0.	-5300.	30000.
1990	0.	-1400.	0.	-5300.	30000.
1991	0.	-1400.	0.	-5300.	30000.
1992	0.	-1400.	0.	-5300.	30000.
1993	0.	-1400.	0.	-5300.	30000.
1994	0.	-1400.	0.	-5300.	30000.
1995	0.	-1400.	0.	-5300.	30000.
1996	0.	-1400.	0.	-5300.	30000.
1997	0.	-1400.	0.	-5300.	30000.
1998	0.	-1400.	0.	-5300.	30000.
1999	0.	-1400.	0.	-5300.	30000.
2000	0.	-1400.	0.	-5300.	30000.
2001	-5000.	-1400.	0.	-5300.	30000.
2002	0.	-1400.	0.	-5300.	30000.
2003	0.	-1400.	0.	-5300.	30000.
2004	0.	-1400.	0.	-5300.	30000.
2005	0.	-1400.	0.	-5300.	30000.
2006	0.	-1400.	0.	-5300.	30000.
2007	0.	-1400.	0.	-5300.	30000.
2008	0.	-1400.	0.	-5300.	30000.
2009	0.	-1400.	0.	-5300.	30000.
2010	0.	-1400.	0.	-5300.	30000.
2011	0.	-1400.	0.	-5300.	30000.
2012	0.	-1400.	0.	-5300.	30000.
2013	0.	-1400.	0.	-5300.	30000.
2014	0.	-1400.	0.	-5300.	30000.
2015	0.	-1400.	0.	-5300.	30000.
2016	0.	-1400.	0.	-5300.	30000.

WOLLASTON-SCHOOL ONLY-1000H-CAPITAL COSTTINCRE BY 15% AND ANNUAL EXP UP

COMPONENT	INTEREST RATE	INFLATION RATE	PRESENT WORTH
CAP COS	13.0	7.8	-232846.
PUMP COS	13.0	7.8	-24297.
HEAT LOSS	13.0	10.0	0.
MAINT	13.0	7.8	-80485.
HEAT SALES	13.0	10.0	605802.

TOTAL PRESENT WORTH OF PROJECT -1 268174.

```
T SPC.INV;3
WOLLASTON CAPITAL COST VALUE FOR FULL SERVICE

COMPONENT          INTEREST RATE    INFLATION RATE    PRESENT WORTH
==========         ========         ==========        ==========
CAP COS                13.0              7.8             320074.

TOTAL PRESENT WORTH OF PROJECT =$    320074.

$ T SPC.INV;4
WOLLASTON CAPITAL COST VALUE FOR SCHOOL ONLY

COMPONENT          INTEREST RATE    INFLATION RATE    PRESENT WORTH
==========         ========         ==========        ==========
CAP COS                13.0              7.8             202039.

TOTAL PRESENT WORTH OF PROJECT =$    202039.

$
```

APPENDIX J

ANALYSIS OF GENERATOR BUILDING HEAT DEMAND

Figure 39 is a graphical presentation of the heat given off by the engine and generator at various loads.

As the load increases, the air for combustion increases. It has been mentioned that this air enters through the wall coil being heated from outside air temperature to +10°C. The additional heating takes place within the generator room and forms part of the building loss together with structural loss and infiltration.

The total building heat losses for various outside air temperatures are also plotted on Figure 39. The difference between the building heat loss lines and the engine set heat emissions gives the net gain in the generator room at various loads.

The following is a typical analysis in the year 1987:

Mean monthly demand	214 kW (Fig. 8)
Load percentage	36%
Combustion air	360 L/s (Table M1)
Outside air	-24°C
Maximum heat gain	52 kW
Maximum heat loss	31 kW (structural, infiltration combustion air)
Minimum heat loss	10.3 kW (structural loss only)
Maximum room gain	41.7 kW
Minimum room gain	21 kW

Assume room temperature at 20°C

Volume of fresh air required to remove maximum heat gain

$$= \frac{41.7}{(20+24) \times 1.2 \times 10^{-3}}$$

$$= 789 \text{ L/s}$$

Let ts be the supply air temperature

Total supply volume = 4483 L/s

4483 x ts = 789 x -24 + 3693 x 20

ts = 12°C

This supply temperature is acceptable

At this engine loading, the combustion air is 360 L/s.

The combustion air load on the coil is 360 x 1.2 x 10^{-3} x 1.0 (10+24) = 14.7 kW

The mean monthly consumption of heat on the coil = 14.7 x 728 = 1070 kW.

The room thermostat will modulate the supply dampers to maintain 20°C.

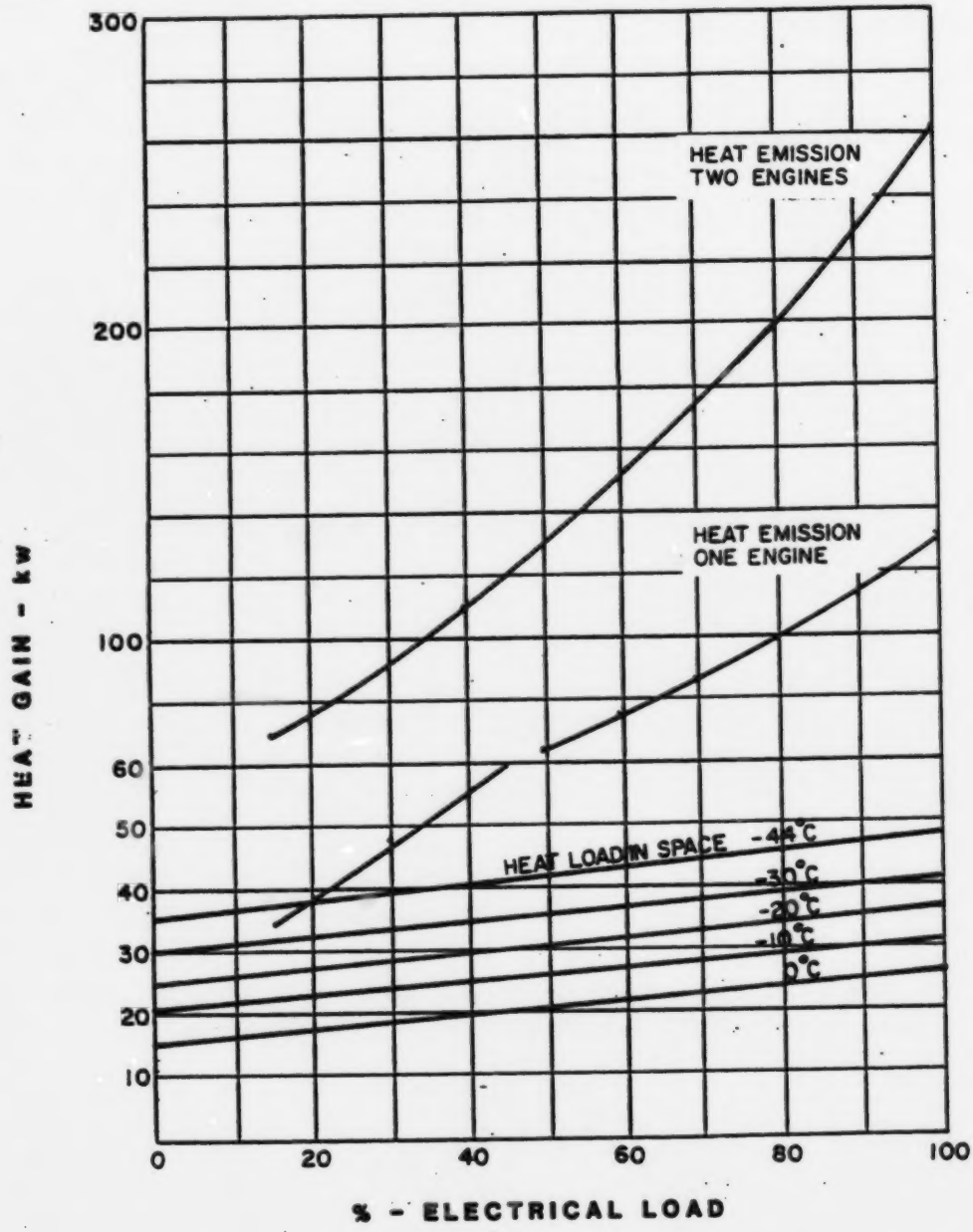
Performing this calculation for various loads for 0°C, -10°C, -20°C, 30°C and 44°C revealed that when the engine load exceeds 66%, the supply air temperature drops below 5°C, an acceptable minimum when the room setpoint is 20°C. If the minimum temperature is fixed at 5°C, the space temperature could rise to 28°C at full engine load. If the setpoint is held at 20°C, the supply temperature will drop below freezing.

To prevent the exhaust fan from starting and imposing a large ventilation load on the foil its control system has to be modified.

The following is a summary of engine load, fuel, air, and exhaust gas capacities used in the analyses of loads and heat production.

Table M1

Electrical Load [%]	Mass of Gas [kg/h]	Electrical Demand [kW]	Fuel L/h	Combustion Air [L/s]
100	3943	600	180.2	892
75	2956	450	135.1	668
66.6	2626	400	123.4	610
50	2067	300	94.5	467
33.3	1500	200	68.54	339
25	1236	150	50.5	279
15	839	90	38.4	190



RADIATION AND GENERATOR

HEAT GAIN

CLIENT/PROJECT **SPC CO-GENERATION STUDY**	SUBJECT
ASSOCIATED ENGINEERING SERVICES LTD AES	APPROVED / DATE / JOB No. — SCALE / DWG No. **FIG. 39**

APPENDIX K

Terms of Reference

Associated Engineering Services Ltd.
RECEIVED
JAN 24 1984
File No.
O.K. to File

SASKATCHEWAN POWER CORPORATION

OUR FILE NO.

1984 January 19
2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1

Associated Engineering Services Ltd.
575 Park Street
Regina, Saskatchewan
S4N 5B2

Dear Sir:

The Saskatchewan Power Corporation Research and Development Centre are inviting proposals for evaluation of waste heat recovery from diesel generators in remote locations. The tasks to be performed under this study are detailed in the attached work statement. A summary of the work is as follows: evaluation of the amount of recoverable heat and its market potential; design and cost estimate for heat recovery and distribution systems; social and environmental impact; and overall economic analysis.

In response to this invitation please provide a complete proposal to undertake the work, including your relevant expertise and capabilities, a cost estimate, and a schedule. Replies have to be received by February 10 in order to be considered.

If you have any questions or require further information, please contact our Mr. R. Graham, telephone (306) 566-2275.

Sincerely,

M.E. Weekes, Ph.D., P.Eng.
Acting Director
Research and Development Centre

Work Statement - Wollaston Lake Co-Generation Study

I. Introduction

This study will evaluate the recoverable heat resource from a diesel-electric generating plant operating at Wollaston Lake. A market for the low grade heat will be identified. A design including the conversion of the diesel plant to co-generation operation and a compatible heat distribution system will be prepared. Such aspects as special social and environmental circumstances of the community will be taken into account in the design. Based on the estimated capital and operating costs, and the expected energy sales and selling price, the lifetime economics will be analyzed.

The results of this study will be compiled in a comprehensive report which is subject to Saskatchewan Power Corporation review and approval prior to being finalized.

II. Tasks to be Undertaken by Consultant

1. Heat Recovery System

The diesel generation plant at Wollaston Lake will be studied to evaluate the recoverable heat. Although the specific generating units at Wollaston Lake are the study's concern, the analysis will be such that it is applicable to similar plants at other locations.

Information on the generating plants will be available through Saskatchewan Power Corporation.

Both the cooling water and exhaust gases resource of heat will be studied.

A design of the diesel plant conversion to co-generation operation will be developed. The practical limitations of the unit will be taken into account in the design. Consideration also has to be given to future expansion of the generation plant.

Any changes in operational and maintenance requirements and safety aspects of the co-generation plant will be cited.

2. Market Evaluation

Information on the operational characteristics such as electric load curves, historic consumptions and demand, and projected electrical load growth for the diesel generation plant at Wollaston Lake will be provided by Saskatchewan Power Corporation. Incorporating this information with the expected heat output of the plant will result in the assessment of the annual available heat.

Careful examination of Wollaston Lake regarding the type of facilities and local activities will be carried out in order to identify appropriate applications of the recoverable heat. The target areas of residential, commercial and institutional buildings will be categorized. An assessment of providing hot water for a laundromat, heating of the community's water distribution system and district heating will be included in the analysis. Possibilities for future demand for low grade heat such as greenhousing, warm water aquaculture, and new local industries shall be addressed.

A balancing of the recoverable heat supply and demand will be the result of this phase of the work.

3. Distribution System

Regardless of where the heat will be utilized within the community, a system to transport the heat from the power plant location will be designed for the most practical applications. The design of this heat distribution system will be dependent on the market. Allowance will be made for any future loads or expansion of the distribution network.

The physical layout of Wollaston Lake as well as information on the topography and soils will be provided by SPC.

Recommendations for the control and monitoring strategies of the heat supply to the entire system and individual users will be included in this portion of the study.

The format of the final design for the distribution system will be compatible with the heat recovery system design.

4. Social and Environment Impact

The social and environmental impact of a total heat recovery system will be investigated. The community's attitude towards the basic concept, the environmental disruption caused by the construction of the co-generation plant and distribution system, local technical capabilities and ability to operate the system, and reaction to the recommended control and monitoring systems are the fundamental issues.

5. Economic Analysis

An estimate for the capital expense of the plant conversion and the heat distribution system will be provided in detail. Operating and maintenance costs will be listed. Any net costs to the consumer such as new heating equipment will be detailed. A recommendation based on a net present value analysis, will be made for determining the economic viability of recovering the heat. Included in the analysis will be both the relative costs of other heating fuel options and the estimated capital cost of the heat recovery and distribution system. This information will result in determining the lifetime economics for both the distribution of the recoverable heat and the use of the heat by individuals.

ASSOCIATED ENGINEERING SERVICES LTD

6. Final System Design and Report

All of the individual requirements detailed in Sections 2 through 6 inclusive will be documented and amalgamated in an appropriate fashion to form a comprehensive final report.

In order to ensure continuous contact during the project, monthly progress reports will be submitted to Saskatchewan Power Corporation. The progress reports can be presented as a one page general summary.

Discussions in the final report will include the validity of extending the results to other northern Saskatchewan communities. The effect of the size, type, and make of individual diesel generators on its ability for co-generation conversion with respect to the design and cost, will be evaluated. The soil/topographical characteristics of Wollaston Lake will be compared to other communities. The physical layout of Wollaston Lake will be discussed with respect to other candidate communities. Long term prospects for operation, maintenance, security and safety of the heat recovery system will be included. A summary will be provided to discuss the realities of recoverable heat utilization in such an application.

One copy of a draft final report will be presented to Saskatchewan Power Corporation by 1984 August 1. Upon their approval of the draft and any recommended changes, the final study report will be prepared and a copy presented to SPC by 1984 September 1.

7. Schedule

The anticipated duration for this study is five months which is reflected in the above completion date of August 1. The consultant, preparing a quotation is asked to present his own schedule for the work in the form of a bar chart.

8. Public Relations

The community of Wollaston Lake may require a presentation of the study results which the consultant will make provisions to attend.

9. Invoicing

Invoices for the study shall be submitted monthly to SPC for the proportion of the work completed. At that time if work is not completed according to the accepted work schedule, reasons for the outstanding work shall be documented and a revised schedule submitted. Failure to meet the schedule will be just cause for holding of payments until the work schedule is completed.

Invoices will be paid promptly, normally within three weeks of receipt of invoice. A 10% holdback, retained by SPC, will be released after issuing the Final Report.

SASKATCHEWAN POWER CORPORATION

OUR FILE NO.

1984 February 29

2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1

Mr. W.J. Delbeke
Associated Engineering Services Limited
575 Park Street
Regina, Saskatchewan
S4N 5B2

Dear Mr. Delbeke:

Please be advised that your company has been selected by us to undertake the study of waste heat recovery from the diesel generators at Wollaston Lake. Of the seven proposals received your submission received top ranking, largely because of your related experience, staff expertise and apparent familiarity with the study area.

Final award of a contract to your company will be dependent on a successful contract initiation meeting which will be scheduled for a mutually convenient date in the very near future. This meeting is necessary to arrive at a joint interpretation of the work statement, and to agree to some modifications that we require. Other items for discussion include finalization of the schedule, identification of milestones, clarification of reporting and invoicing procedures, establishment of a firm contract cost limitation, and implementation of cost control procedures.

The main issue that we wish to raise concerning modifications to the work statement is the level of effort to be spent on the horticultural aspects. In your proposal you discussed possible reductions in this area in order to increase the design work on the basic system. We would like to explore this further, perhaps reducing the work on the horticultural aspects to about one fifth of that proposed. This, of course, raises the question of whether the proposed sub-consultant will still be required.

The areas in which we would like to see the level of effort increased are as follows: detailed discussion of heat recovery methods from the diesel generators; identification of the maximum, minimum and average heat supply; and detailed economic analysis with respect to both the supplier and the customer. We would also expect that the study will yield sufficient details of the proposed design as to be directly useful in developing tender specifications and drawings for an actual installation, if warranted.

I do not anticipate that any difficulties will arise in negotiating these revisions to the work statement, or that they will delay the final report beyond the September 1 deadline which must remain firm. Randy Graham of our office will be contacting you shortly to set the date for the contract initiation meeting.

Yours truly,

Michael E. Weekes, Ph.D., P.Eng.
Acting Director
Research and Development Centre

Associated Engineering Services Ltd. - Regina
RECEIVED
MAR 13 1984
File No. SJ65
B.K. to File

SASKATCHEWAN POWER CORPORATION

1984 March 7
2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1

Mr. W. J. Delbeke
Associated Engineering Services
Limited
575 Park Street
Regina, Saskatchewan
S4N 5B2

Dear Wayne:

Re: Wollaston Lake Waste Heat Recovery Study

Further to our meeting of March 6 at which the project methodology was clarified, I would like to document the following discussion points. The revisions from your initial proposal as stated below will now constitute where applicable, the terms of our contract with you. The work to be undertaken is as follows:

- AESL will prepare a new work statement and present the same to SPC. Two of the major changes include: study the new power plant location and the proposed new school, and reduce horticultural investigations down to a level that can be handled within AESL so that external consulting services will not be required. With the reduction in horticultural work, the design drawings presented in the final report will be enhanced towards attaining tender documents.

- AESL will provide SPC with a list of very specific data that they require. Included on the list will be the people responsible for supplying the individual data. One very important piece of data required is a load curve. SPC will provide a rough approximation of the load curve and AESL will survey northern utilities to determine if they have load curves available.

- SPC will provide reference information available on two similar studies done at Oxford House, Manitoba, and Lac La Marte, N.W.T.

- As proposed in the original work statement, the question of whether or not an external environmental agency is required will be assessed after the initial design of the waste heat system is completed. This design would encompass the amount of heat available for applications other than school space heating.

- Some of the study's specific details will include; sensitivity analysis in the economic analysis; AESL will estimate the new school heating load; a portion of the extrapolation of its study to other locations will include residential district heating viability; monitoring/measuring of heat supplied to the school will be included; the applicable route through the community for any distribution network will be discussed fully in terms of both technical and social considerations; and AESL will communicate directly with diesel generator manufacturers to acquire any information and discuss effects of implementing waste heat recovery.

- AESL will provide SPC with immediate notice with respect to potential budget overruns. At that time a meeting will be held to discuss revisions to work required in order to meet the project budget. The project cost limitation will not be exceeded.

- The first invoice statement and accompanying one page progress report will be for the period ending April 1, and will be submitted to SPC by April 9. The schedule for the future invoices and reports will be monthly from that point on.

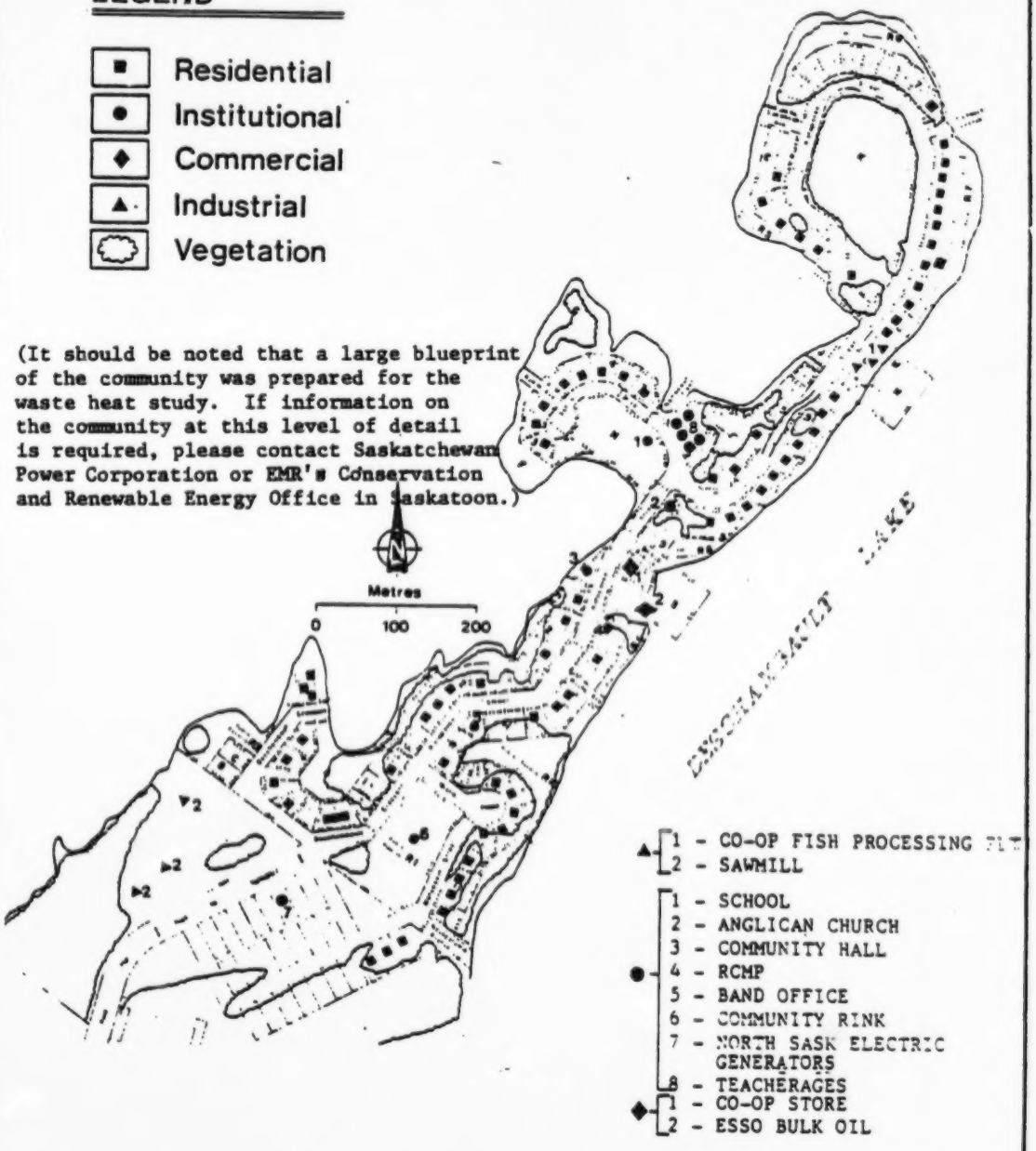
I trust that the above accurately reflects our discussions and the agreed revisions and responsibilities. I request that AESL will be responsible for preparation of minutes of any future project meetings. Anytime you wish to discuss any portion of this work please contact me.

Yours truly,

Randal Graham
Research Engineer
Research and Development Centre

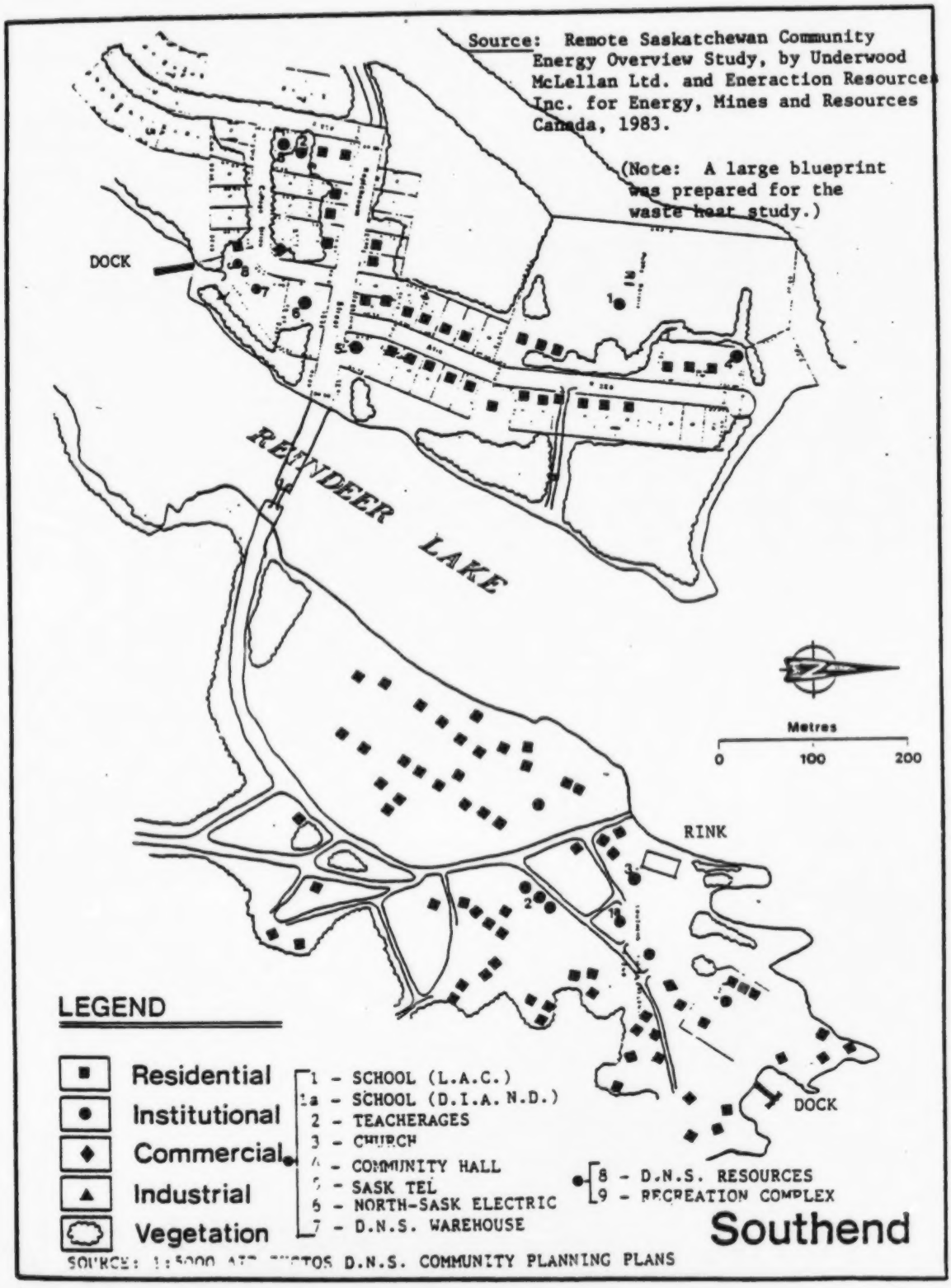
cc. M. Weekes

Source: Remote Saskatchewan Community Energy Overview Study, by Underwood McLellan Ltd. and Eneraction Resources Inc. for Energy, Mines and Resources Canada, 1983.


LEGEND
Residential
Institutional
Commercial
Industrial
Vegetation
(It should be noted that a large blueprint of the community was prepared for the waste heat study. If information on the community at this level of detail is required, please contact Saskatchewan Power Corporation or EMR's Conservation and Renewable Energy Office in Saskatoon.)
N
Metres
0
100
200
DESCHAMBAULT LAKE
1 - CO-OP FISH PROCESSING PLT
2 - SAWMILL
1 - SCHOOL
2 - ANGLICAN CHURCH
3 - COMMUNITY HALL
4 - RCMP
5 - BAND OFFICE
6 - COMMUNITY RINK
7 - NORTH SASK ELECTRIC GENERATORS
8 - TEACHERAGES
1 - CO-OP STORE
2 - ESSO BULK OIL

Deschambault Lake

SOURCE: 1:5000 AIR PHOTO'S 1981 DNS COMMUNITY PLANNING FIELD NOTES & LEGAL PLANS-1979


Source: Remote Saskatchewan Community Energy Overview Study, by Underwood McLellan Ltd. and Eneraction Resources Inc. for Energy, Mines and Resources Canada, 1983.
(Note: A large blueprint was prepared for the waste heat study.)
DOCK
REINDEER LAKE
Metres
0
100
200
RINK
DOCK
LEGEND
Residential
Institutional
Commercial
Industrial
Vegetation
1 - SCHOOL (L.A.C.)
1a - SCHOOL (D.I.A. N.D.)
2 - TEACHERAGES
3 - CHURCH
4 - COMMUNITY HALL
5 - SASK TEL
6 - NORTH-SASK ELECTRIC
7 - D.N.S. WAREHOUSE
8 - D.N.S. RESOURCES
9 - RECREATION COMPLEX
Southend
SOURCE: 1:5000 AT... PHOTOS D.N.S. COMMUNITY PLANNING PLANS